

TECHNICAL SPECIFICATION



**Industrial-process measurement, control and automation –
Part 1: system interface between industrial facilities and the smart grid**

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**Industrial-process measurement, control and automation –
Part 1: system interface between industrial facilities and the smart grid**

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62872-1, which is a technical specification, has been prepared by IEC technical committee 65: Industrial-process measurement, control and automation.

This first edition edition cancels and replaces IEC TS 62872, published in 2015. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to IEC TS 62872:

- Normative references, Terms and definitions, and Abbreviations were updated;
- Subclause 5.1 was reformulated with price-based and incentive-based demand response;
- Subclause 5.8.3 “Example of data and data type” was added;
- New actors were added in Annex A;
- Use cases FG-7xx and FG-8xx were added in Annex A;
- Annex B “Use cases of incentive-based DR programs” was added.

The text of this Technical Specification is based on the following documents:

Enquiry draft	Report on voting
65/731/DTS	65/743/RVDTS

Full information on the voting for the approval of this Technical Specification can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A review of this document will be carried out not later than 3 years after its publication with the options of: extension for another 3 years; conversion into an International Standard; or withdrawal.

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INTRODUCTION

The World Energy Outlook 2017 [19]¹ reported that industry consumed over 40 % of world electricity generation in 2015. Furthermore, industry itself is a significant generator of internal power, with many facilities increasingly implementing their own generation, co-generation and energy storage resources. As a major energy consumer, the ability of some industries to schedule their consumption can be used to minimize peak demands on the electrical grid. As an energy supplier, industries with in-house generation or storage resources can also assist in grid load management. While some larger industrial facilities already manage their use and supply of electric power, more widespread deployment, especially by smaller facilities, will depend upon the availability of a readily available standard interface between industrial automation equipment and the “smart grid”.

NOTE In this document “smart grid” is used to refer to the external-to-industry entity with which industry interacts for the purpose of energy management. In other documents this term can be used to refer to all of the elements, including internal industrial energy elements, which work together to optimize energy generation and use.

Industry is a major consumer of electric power and in many cases this consumption can be scheduled to assist in minimizing overall peak demands on the smart grid. In addition, many industrial facilities have in-house generation or storage resources. These facilities can assist in smart grid load and supply management. For example, in-house generation can supply energy to the smart grid and to the facility. Furthermore, storage resources can assist in smart grid load management. While some larger industrial facilities already manage their use and supply of electric power, more widespread deployment, especially by smaller facilities, will depend upon the availability of readily available standard automated interfaces.

Standards are already being developed for home and building automation interfaces to the smart grid; however, the requirements of industry differ significantly and are addressed in this document. For industry, the planning of energy resources and production processes are under the responsibility of the facility energy planner and production planner and the operations are under the responsibility of the facility energy operator and production operator.

Incorrect operation of a resource could impact the safety of personnel, the facility, the environment or lead to production failure and equipment damage. In addition, larger facilities may have in-house production planning capabilities which might be co-ordinated with smart grid planning, to allow longer term energy planning.

¹ Numbers in square brackets refer to the Bibliography.

INDUSTRIAL-PROCESS MEASUREMENT, CONTROL AND AUTOMATION –

Part 1: system interface between industrial facilities and the smart grid

1 Scope

This part of IEC 62872 defines the interface, in terms of information flow, between industrial facilities and the “smart grid”. It identifies, profiles and extends where required, the standards needed to allow the exchange of the information needed to support the planning, management and control of electric energy flow between the industrial facility and the smart grid.

The scope of this document specifically excludes the protocols needed for the direct control of energy resources within a facility where the control and ultimate liability for such control is delegated by the industrial facility to the external entity (e.g. distributed energy resource (DER) control by the electrical grid operator).

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62264-1:2013, *Enterprise-control system integration – Part 1: Models and terminology*

IEC 62443 (all parts), *Industrial communication networks – Network and system security*

IEC TS 62443-1-1:2009, *Industrial communication networks – Network and system security – Part 1-1: Terminology, concepts and models*

IEC 62443-2-1, *Industrial communication networks – Network and system security – Part 2-1: Establishing an industrial automation and control system security program*

IEC TR 62443-3-1, *Industrial communication networks – Network and system security – Part 3-1: Security technologies for industrial automation and control systems*

IEC 62443-3-3, *Industrial communication networks – Network and system security – Part 3-3: System security requirements and security levels*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1 General

3.1.1 profile

set of one or more base standards and/or other profiles and, where applicable, the identification of chosen classes, conforming subsets, options and parameters of those base standards, or profiles necessary to accomplish a particular function

[SOURCE: ISO/IEC TR 10000-1:1998, 3.1.4, modified – "ISPs" has been replaced by "profiles".]

3.1.2 level

group of functions categorized with the functional hierarchy model of production systems defined in IEC 62264-1

Note 1 to entry: The highest level, Level 4, typically includes enterprise resource planning and similar functions, while the lowest level, Level 0, represents the physical industrial process itself.

3.1.3 level 4

functions involved in the business-related activities needed to manage a manufacturing organization

[SOURCE: IEC 62264-1:2013, 3.1.16]

3.1.4 level 3

functions involved in managing the work flows to produce the desired end-products

[SOURCE: IEC 62264-1:2013, 3.1.17]

3.1.5 level 2

functions involved in monitoring and controlling of the physical process

[SOURCE: IEC 62264-1:2013, 3.1.17]

3.1.6 level 1

functions involved in sensing and manipulating the physical process

[SOURCE: IEC 62264-1:2013, 3.1.18]

3.1.7 level 0

actual physical process

[SOURCE: IEC 62264-1:2013, 3.1.19]

3.1.8 enterprise

one or more organizations sharing a definite mission, goals and objectives which provides an output such as a product or service

[SOURCE: IEC 62264-1:2013, 3.1.10]

3.1.9

area

physical, geographical or logical grouping of resources determined by the site

[SOURCE: IEC 62264-1:2013, 3.1.2, modified – The example has been removed.]

3.1.10

site

identified physical, geographical, and/or logical component grouping of a manufacturing enterprise

[SOURCE: IEC 62264-1:2013, 3.1.39]

3.1.11

facility

industrial facility

site, or area within a site, that includes the resources within the site or area and includes the activities associated with the use of the resources

[SOURCE: IEC 62264-1:2013, 3.1.20, modified – The preferred term facility and the admitted term industrial facility have been replaced by facility.]

3.1.12

planner

facility energy planner

entity responsible for the advanced planning of facility energy use, storage and generation, taking into account the requirements of future production and the overall operation of the facility

Note 1 to entry: The facility energy planner is responsible for defining the overall future energy plan for the facility, to include both the energy requirements of production and the overall needs and capabilities of the facility to generate, store, and consume energy.

Note 2 to entry: Plans developed by the facility energy planner will typically be made at least a day prior to intended use.

Note 3 to entry: The facility energy planner will assemble the overall energy plan based on the individual plans developed by production planners and the non-production requirements and capabilities of the facility.

3.1.13

production planner

entity responsible for developing, monitoring and modifying the production plan based on facility requirements and the availability of inputs

Note 1 to entry: Example of inputs are equipment, labour, raw materials and energy.

3.1.14

facility energy operator

entity responsible for the minute by minute supply of energy to support current production and current facility operation

Note 1 to entry: The facility energy operator monitors facility energy use, generation and storage, and makes adjustments in response to changes related to shifting energy supplies, material disruptions, and equipment breakdowns.

3.1.15

production operator

entity responsible for the minute by minute use of energy to carry out production plans, and authorized to respond to real-time changes based on feed-back from the process and other internal or external event

Note 1 to entry: The production plan is given from production planner.

3.2 Models in automation

3.2.1

asset

physical or logical object owned by or under the custodial duties of an organization, having either a perceived or actual value to the organization

Note 1 to entry: In the case of industrial automation and control systems the physical assets that have the largest directly measurable value may be the equipment under control.

[SOURCE: IEC TS 62443-1-1:2009, 3.2.6]

3.2.2

automation asset

asset with a defined automation role in a manufacturing or process plant

Note 1 to entry: It would include structural, mechanical, electrical, electronics and software elements (e.g. controllers, switches, network, drives, motors, pumps). These elements cover components, devices but not the plant itself (machine, systems). It would not include human resources, process materials (e.g. raw, in-process, finished), or financial assets.

3.2.3

process

set of interrelated or interacting activities that transforms inputs into outputs

[SOURCE: ISO 14040:2006, 3.11]

3.2.4

product

result of labour or of a natural or industrial process

Note 1 to entry: This term is defined by "any goods or service" in IEC 62430 [11] and ISO 20140-1 [18]. The European Commission adopts a similar understanding in the directive "Ecodesign requirements for energy-related products". In the context of this document, the term "product" does not cover the automation assets but only the output of the manufacturing or process plant.

[SOURCE: IEC TR 62837:2013, 3.7.7]

3.3 Models in energy management system and smart grid

3.3.1

smart grid

SG

electric power system that utilizes information exchange and control technologies, distributed computing and associated sensors and actuators, for purposes such as to integrate the behaviour and actions of the network users and other stakeholders, and to efficiently deliver sustainable, economic and secure electricity supplies

Note 1 to entry: In this document, smart grid is the counterpart system to which FEMS is connected.

[SOURCE: IEC 60050-617:2011, 617-04-13, modified by adding abbreviation and Note 1 to entry]

3.3.2

smart meter

SM

embedded-computer-based energy meter with a communication link

Note 1 to entry: In this document smart meters are used to measure both the consumption and supply of energy by the facility. They may also be deployed within the facility to measure internal energy flows.

3.3.3

utility smart meter

USM

smart meter deployed by the utility company to measure energy consumption and supply by the facility

Note 1 to entry: This meter typically forms part of the advanced metering infrastructure of smart grid.

3.3.4

facility smart meter

FSM

smart meter deployed and used by the facility to measure energy flows

Note 1 to entry: This meter will normally communicate with the FEMS.

3.3.5

distributed energy resource

DER

energy resource, often of a small size, operated by the utility to augment the local supply of energy

Note 1 to entry: In this document, DER, in contrast to FER, is used to refer to resources under the direct control of the utility. Such resources may include generation and/or storage capabilities.

3.3.6

facility energy resource

FER

energy resource, operated by the facility, which is used to supply energy to the facility and which may also be used to provide energy to the grid

Note 1 to entry: This terminology, rather than distributed energy resource (DER) terminology, is used to emphasize that the FER is operated by the facility and not under the direct control of the utility. Such resources may include generation and/or storage capabilities.

3.3.7

demand response

DR

mechanism to manage customer load demand in response to supply conditions, such as prices or availability signals

3.3.8

price-based demand response

PBDR

mechanism that give customers time-varying rates that reflect the value and cost of electricity in different time periods

Note 1 to entry: Armed with this information, customers tend to use less electricity at times when electricity prices are high.

3.3.9

time of use

TOU

rate with different unit prices for usage during different blocks of time, usually defined for a 24-hour day

Note 1 to entry: TOU rates reflect the average cost of generating and delivering power during those time periods.

3.3.10

day-ahead price

DAP

rate notified on a day-ahead basis, in which the price for electricity fluctuates hourly reflecting changes in the wholesale price of electricity

3.3.11**real-time price****RTP**

rate notified on hourly-ahead basis, in which the price for electricity fluctuates hourly reflecting changes in the wholesale price of electricity

3.3.12**incentive-based demand response****IBDR**

mechanism supported by soliciting demand response behaviour, commitment to agreed demand response and programs that pay participating customers to reduce their loads at times requested by the program sponsor

Note 1 to entry: The no-participation in solicited demand response behaviour does not incur any penalty; examples are DLC and EDRP.

Note 2 to entry: The no-participation in committed agreed demand response behaviour entails a penalty; examples are I/C, DB, CMP and ASM.

3.3.13**direct load control****DLC**

one of IBDR programs, in which the SG operator remotely shuts down the load of a facility to address system reliability contingencies, in exchange of paying the facility participation payment in advance

3.3.14**interruptible/curtailable load****I/C**

one of IBDR programs, in which the SG operator issues “incentive” to a facility for agreeing to reduce load during system contingencies, a facility will be penalized if it does not reduce load

3.3.15**emergency demand response program****EDRP**

one of IBDR programs, in which the SG operator provides incentive payment to a facility for measured load reduction during a reliability-triggered event, no penalty is imposed if the facility does not respond

3.3.16**demand bidding****DB**

one of IBDR programs, in which the SG operator allows a facility to bid load reduction into the energy market, a facility with accepted bid shall reduce load as contracted, otherwise it faces a penalty

3.3.17**capacity market program****CMP**

one of IBDR programs, in which the SG operator provides a facility with guaranteed payment for committing to provide predefined load reduction as the system capacity, a facility will face a penalty if it does not reduce load during a DR event

3.3.18**ancillary service market****ASM**

one of IBDR programs, in which the SG operator allows a qualified facility to bid load reduction into the ancillary market as operating reserves, a facility with accepted bid shall curtail load when called by the SG operator, otherwise it faces a penalty

3.3.19
facility energy management system
FEMS

system providing the functionality needed for the effective and efficient operation of energy generation, storage and consumption within the industrial facility, and which provides the necessary information interface with the smart grid

[SOURCE: IEC TS 61968-2:2011, 2.101, modified – The definition has been rewritten]

3.3.20
utility gateway
UG

function within FEMS responsible for the connection with the smart grid

Note 1 to entry: It is a function within FEMS.

3.3.21
energy generation system
EGS

energy resource capable of creating electric energy from other sources of energy or process wastes

EXAMPLE Combined heat and power systems, photo-voltaic cells, wind power generators.

3.3.22
energy storage system
ESS

energy resource capable of storing energy for later use

EXAMPLE Batteries, flywheels, pumped hydro storage, electrical vehicles, fuel cells.

3.3.23
facility power line
FPL

network, which distributes energy to individual industrial equipment within a facility

3.3.24
schedulable processing task
ST

task for which energy demand can be scheduled among multiple operating modes, where each mode has a different production rate and energy demand, such as heating, cooling, packaging, etc.

3.3.25
non-schedulable processing task
NST

task for which energy demand shall be satisfied immediately, such as rolling in steel manufacturing, assembling in automobile industry, etc.

3.3.26
monitor and control agent
MCA

agent that monitors and controls processing operations of a task

3.3.27
energy management agent
EMA

agent that monitors the energy consumption and controls the electric load of a task

3.3.28**power source switch**

switch which selects the energy source of a task

3.3.29**non-shiftable equipment****NSE**

equipment whose operation cannot be re-scheduled

3.3.30**controllable equipment****CE**

equipment whose energy demand can be controlled among multiple operating levels, each of which has a different energy demand

3.3.31**shiftable equipment****SE**

equipment that can be operated at an earlier or later time

3.3.32**firewall**

inter-network connection device that restricts data communication traffic between two connected networks

4 Abbreviated terms

APO	Advanced Planning and Optimization
ASM	Ancillary Service Market
CE	Controllable Equipment
CHP	Combined Heat and Power (co-generation) Equipment
CMM	Computerized Maintenance Management
CMP	Capacity Market Program
DAP	Day-ahead Price
DB	Demand Bidding
DCS	Distributed Control System
DER	Distributed Energy Resource
DLC	Direct Load Control
DR	Demand Response
EDRP	Emergency Demand Response Program
EGS	Energy Generation System
EMA	Energy Management Agent
EMS	Energy Management System
ERP	Enterprise Resource Planning
ESS	Energy Storage System
FEMS	Facility Energy Management System
FER	Facility Energy Resource
FG	Facility-Grid (Use Case)
FSM	Facility Smart Meter
FUS	Facility User Story

GW	Utility Gateway
HMI	Human Machine Interface
IBDR	Incentive-based Demand Response
I/C	Interruptible/curtailable Load
I/O	Input Output
ICT	Information and Communications Technology
LAN	Local Area Network
LIMS	Laboratory Information Management System
MCA	Monitor and Control Agent
MES	Manufacturing Execution System
NSE	Non-shiftable Equipment
NST	Non-schedulable Processing Task
PBDR	Price-based Demand Response
PLC	Programmable Logic Controller
PV	Photo Voltaic
RTP	Real-time price
SCADA	Supervisory Control and Data Acquisition
SE	Shiftable Equipment
SG	Smart Grid
SM	Smart Meter
ST	Schedulable Processing Task
TOU	Time of Use
UG	Utility Gateway
USM	Utility Smart Meter
UUS	Utility User Story
VEN	Virtual End Node
VTN	Virtual Top Node
WAN	Wide Area Network
WMS	Warehouse Management System

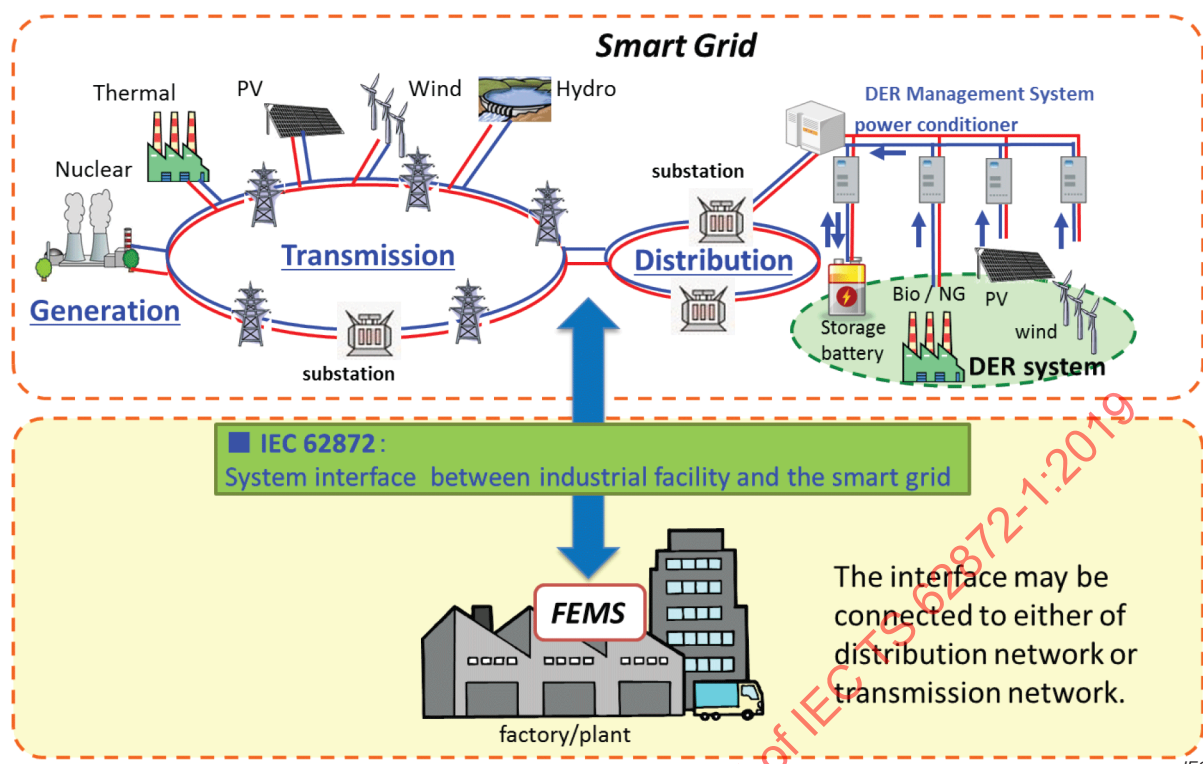
5 Requirements

5.1 Considerations and approaches in industry

5.1.1 General

As discussed in the Introduction, the efficient and safe management of energy consumption by industry, and energy supply by industry, can result in reduced peak loads of smart grid and the ability to better use intermittent and less predictable energy sources such as wind and solar sources. It will also permit the smart grid and industry to co-operate to better address occasional and emergency energy shortages. To manage this flow of energy, a communications interface is required, as represented in Figure 1.

While industry is well placed to contribute in this way, such contributions usually take into account the priorities of industrial production. Typical industrial facilities operate according to production schedules, which once started often cannot be suspended in the short term.

**Key**

Red line: electricity line
Blue line: informational line

Figure 1 – Overview of interface between FEMS and smart grid

Furthermore, power interruptions can impair safe facility operation or impact production quality. In most cases, facility equipment is under the direct control of the facility control systems and should meet the requirements of production and remain the responsibility of the facility operator. This represents a significant difference from building and home automation where external controls may affect internal operations and have significantly less impact. Any direct control of internal facility equipment by external entities can raise potential facility safety, production quality, and facility liability concerns. Incorrect operation of a resource could impact the safety of personnel, the facility, the environment or lead to production failure and equipment damage.

The interface shall be designed to provide adequate confidence that cooperation with the smart grid cannot compromise the safety and security of the facility.

The extent to which the internal energy resources (including energy loads) of an industrial facility may be influenced by the smart grid operator or an intermediary, such as an aggregator, will vary from one facility to another. Furthermore, the extent of such control may change over time depending upon the internal production schedules of the facility. Thus, a flexible approach needs to allow the arrangements to be profiled for blocks of time to match facility production schedules, and to ensure that during critical periods of time, control of energy resources remains with the facility operator.

It is also essential to recognize that grid operations are subject to stringent system-wide stability controls, and that the coupling of any facility to the grid should be consistent with the grid operator's objective of maintaining grid stability and should leverage existing procedures as much as feasible.

5.1.2 Approaches to maintain grid stability

For the purpose of this document, it is convenient to consider the approaches taken by grid operators (and potentially aggregators) to interact with external actors to maintain grid stability under two general categories: direct operation and operation request.

Under direct operation, the grid operator takes direct operation of the energy resource, and uses knowledge of the resource's characteristics to directly manage the resource in real time. Such direct operation would only be acceptable to industrial facilities during facility shut-down or at other times when production is not at risk. Grid operators have typically used these arrangements to manage "distributed energy resources" (DER) and protocols to implement such direct control have been, and are being, developed within IEC.

Under operation request, the grid operator issues requests for demand reductions to address predicted energy supply short falls. Although typically used today to reduce the electrical load on the grid, this document assumes extensions of this approach will be used to support requests for increases in the electrical load, or increases or decreases in electrical supply provided by a facility to the grid. Thus, this document encourages the extension of existing standards wherever possible to address the additional requirements of industrial facilities.

5.1.3 Price-based and incentive-based demand response

As discussed above, it is also the case that the operating profile of a facility may need to change from time to time to meet facility schedules, and the facility can potentially adjust schedules if given enough information about the future needs of the grid. Thus, this document recognizes the need to provide mechanisms to permit the industrial facility and the grid operator (or aggregator) to evaluate and agree on the scheduling of blocks of time when a specific energy profile arrangement can be used. For example, the facility may wish to indicate to the grid that a resource is available for certain periods of time, for example during off-shift times. At other times the facility may wish to indicate that it cannot respond to demand response requests.

Figure 2 provides a graphic which depicts the general approach common today for grid management of demand response [20].

In Figure 2, references to months, days, hours, and minutes should be taken as generally representative of the time scales intended.

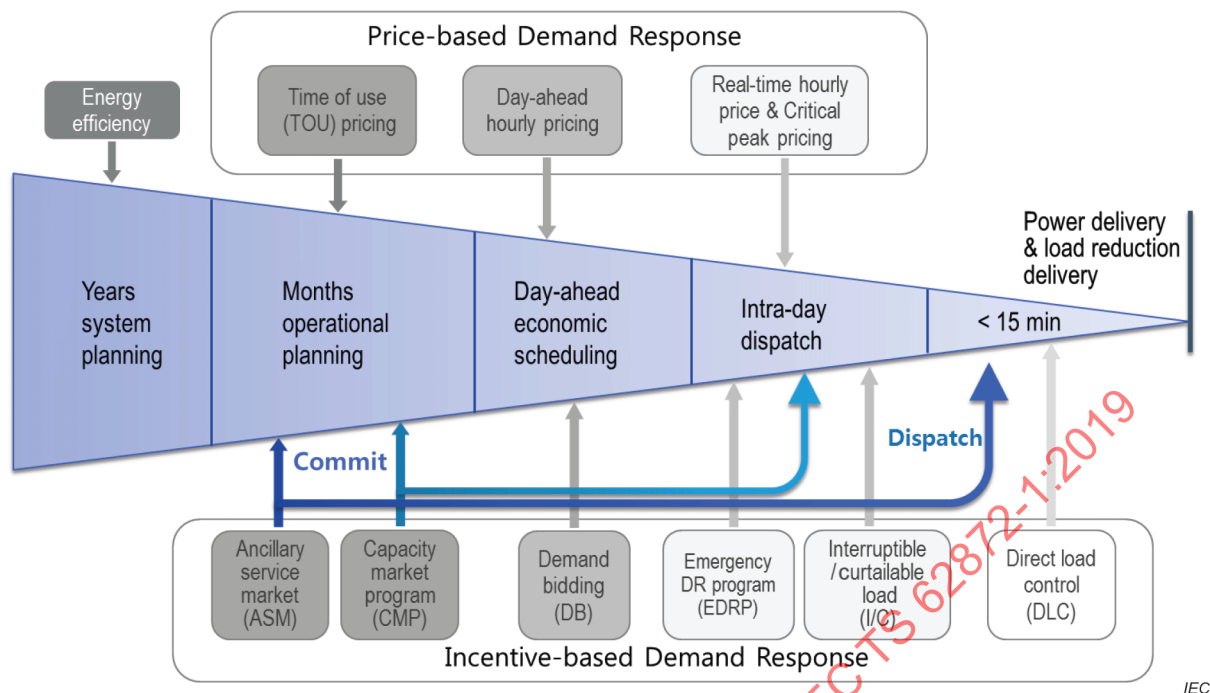


Figure 2 – General approach common today for grid management of DR

In Figure 2 the elements at the top of the figure denote the techniques used for “price-based demand response”. This assumes that the offer of differing prices can affect demand. Time of use (TOU) pricing is becoming common today, and allows consumers to routinely schedule consumption at certain times-of-day, or on week-ends, when the energy supplier is confident that other energy demands will be low. These pricing arrangements require the grid operator to fix prices, and times-of-day, well in advance and using a model suitable for long periods of time, for example seasonally. Of more value to the grid operator are the day-ahead hourly pricing and real-time hourly pricing models, where the operator can use current grid demand to offer pricing more exactly matched to encouraging the demand response currently needed. However, such hourly pricing models require the consumer to more proactively monitor price offers and to be able to adjust their own energy plans in similar time scales to maximize their energy savings.

TOU models may be used by some facilities but maximum savings are envisaged when day-ahead and real-time pricing arrangements can be used to access more attractive energy pricing. For these arrangements, it will be necessary to define means by which the parties can communicate the offered pricing and for the parties to agree on resulting energy plans.

Figure 2 also identifies the techniques used for “incentive-based demand response”. Typically, these programs offer an incentive to the consumer (e.g. a reduced pricing structure) if the consumer agrees to offer a “service” response on demand from the grid. The “services” to be provided under these programs are typically those for which a quick response is required, like a service where a specific amount of demand shall be reduced immediately to address an immediate short-fall in grid generation. Typically, if the response is not provided promptly, a penalty is assessed.

As shown in Figure 2, for incentive based programs, a “commitment” to the program is made beforehand while the “dispatch”, or activation, of the service response is made close to real-time (as shown by the two arrows in the figure).

In summary, Figure 2 indicates the need to support exchanges between the parties both “a day ahead” to set into place those items needed for planning, and exchanges closer to real-time to manage the actual delivery of the energy plan.

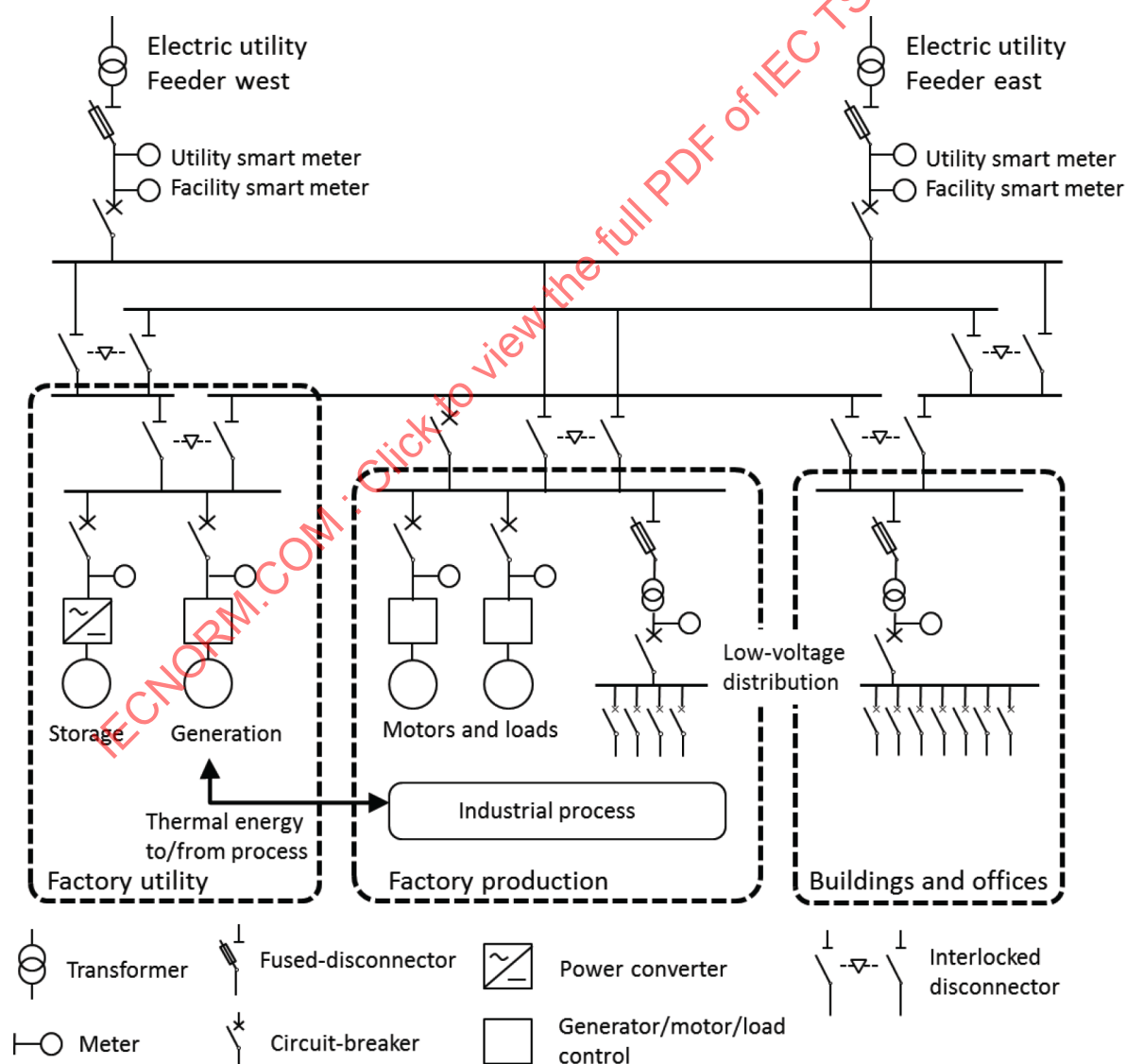
NOTE While the term “a day ahead” is used here, in practice this could be weeks or even months ahead, depending upon the specific arrangement.

Communications corresponding to interactions in the longer-term related to scheduling would correspond to relatively slower interactions between the grid and the facility to arrive at production schedules and communications needed to adjust these arrangements nearer to the scheduled time of energy use or delivery.

5.2 Architecture requirements

5.2.1 General

Figure 3 provides a physical view of how an industrial facility might make its electric power connection to the smart grid. In this example, two electrical connections are made to the smart grid to increase the reliability of power delivery. Internally, the facility might contain a range of electrical consuming, generation and storage equipment. Interconnection and synchronizing equipment is used to route and coordinate electric power flows internally within the facility, and between the facility and the smart grid. In many cases there may additionally be thermal energy transfers between the equipment and the industrial process, for example using combined heat and power (CHP) equipment.

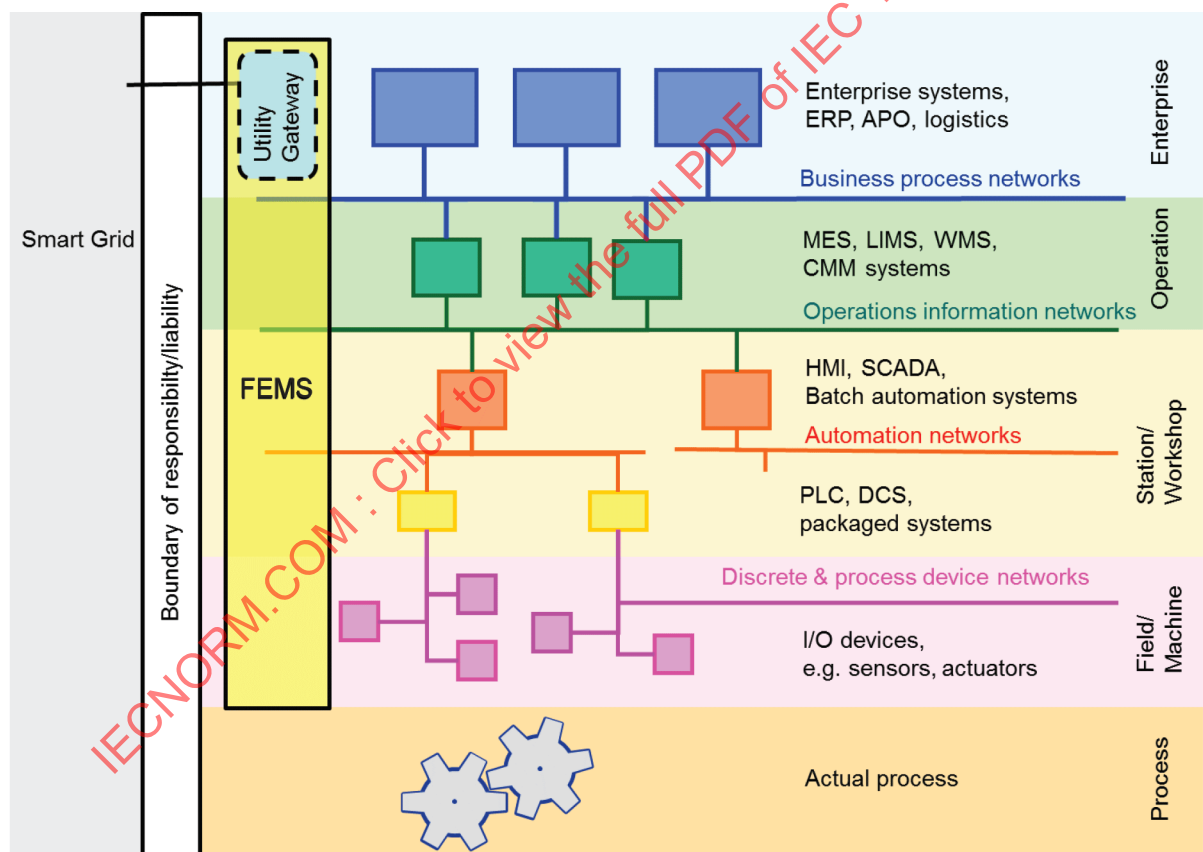


IEC

Figure 3 – Example facility electric power distribution

A typical facility will deploy various metering and control devices to manage the electric and thermal energy flows within the facility. Figure 3 depicts two smart meters at each of the facility's incoming feeders permitting independent metering by the smart grid and the facility. Internally, various meters might be deployed to allow the facility to manage and account for its own internal energy use. For example, the "factory utility" might operate as its own cost centre. Control devices will be deployed to manage storage, generation, and motors and loads, as well as to manage power synchronization and the interconnection of the equipment. These meters and control devices will form part of the facility enterprise and control systems described below.

Figure 4 presents a view of the facility enterprise and control systems aligned to IEC 62264 (all parts) [9]. The operation of all resources within the facility will be under the control of the facility manager and facility automation. Resources will include generation and storage as well as capabilities to manage production planning. At the top of the figure, enterprise planning and logistics elements are used by facility management to manage production planning. For example, the facility may have options to schedule production -shifts with particular energy consumption or production (e.g. from cogeneration) profiles. Elements at lower levels of the hierarchy are used to implement production plans in real time and to ensure safe operation. For example, some processes, once started, cannot be stopped without impacting product quality or facility safety.



IEC

Figure 4 – Facility enterprise and control systems

The operation of the facility, and all liability issues related to such operation, will normally remain the responsibility of the facility manager and associated facility automation. The smart grid will need to be isolated from such control and facility operation liability.

Thus, the utility gateway should isolate the facility from the smart grid and direct control of facility equipment, while at the same time exposing sufficient characteristics of the facility, and production sequence options, to allow the effective planning and transfer of energy between the smart grid and the facility.

5.2.2 Energy management in industrial facilities

5.2.2.1 General

Energy management in industrial facilities differs significantly from that typically found in home and building environments. Industrial facilities often have far larger energy consumption, generation and/or storage capacities. They often include sophisticated energy planning and operating capabilities to ensure cost effectiveness, availability, compliance to regulations and safe operation of the equipment.

Clause A.1 discusses these characteristics in more detail, however in summary:

- Many facilities have significant energy demands and the ability to reschedule (“shift”) this demand to avoid times of peak demand in the smart grid.
- Many facilities have significant energy generation and/or storage resources associated with their industrial processes, and the potential ability to supply energy to the smart grid.
- Work centers (e.g. process cell, production unit, production line) within an industrial facility work together according to production plans to create a final product. In addition to the cost of energy, these plans normally take into account a range of other factors, including the availability of raw and intermediate materials, and labour. Thus, many facilities have significant planning capabilities which can be used to develop energy plans to better co-ordinate the future use and potential supply of energy to the smart grid.
- Often the operation of an industrial process cannot be interrupted once started. A mismatch between the energy supply and demand can cause irretrievable technical and financial problems, such as equipment damage and production which does not meet quality requirements. Industrial facilities are typically very complex, with particular designs to meet specific manufacturing and production objectives. This diversity complicates the standardization of an interface for energy management.

In order to have a common understanding of energy management in industrial facilities, a common model is required for different industrial facilities. The model requires common definitions of:

- model elements of energy management in industrial facilities;
- model architecture of energy management in industrial facilities; and
- approaches of energy management in industrial facilities.

The rest of 5.2.2 describes the planning and scheduling functions needed to coordinate the use and supply of energy to the smart grid.

5.2.2.2 Model elements

Figure 5 lists all the elements which are essential to build an energy management model in industrial facilities. Each element is uniquely identified by one graphic symbol.

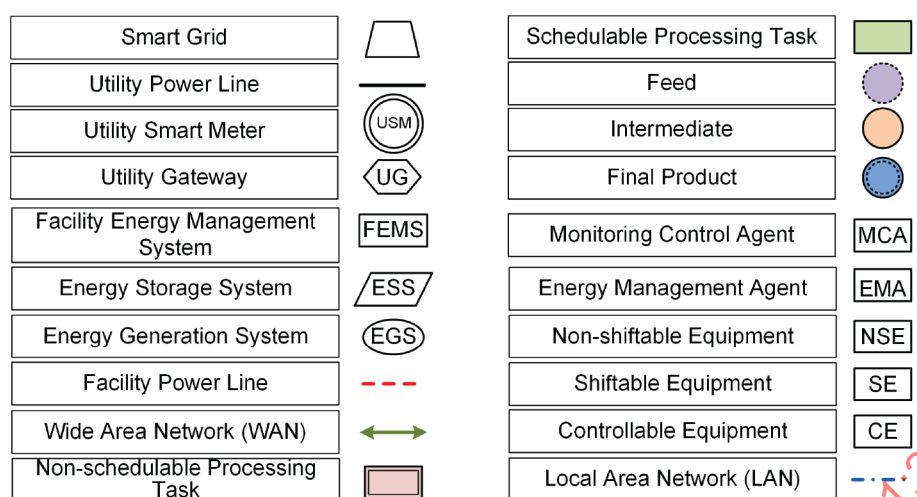


Figure 5 – Model elements

5.2.2.3 Model architecture

5.2.2.3.1 General

Figure 6 represents the energy management model in industrial facilities, which illustrates the interrelationship of model elements. The model architecture consists of main architecture (a) and task structure (b).

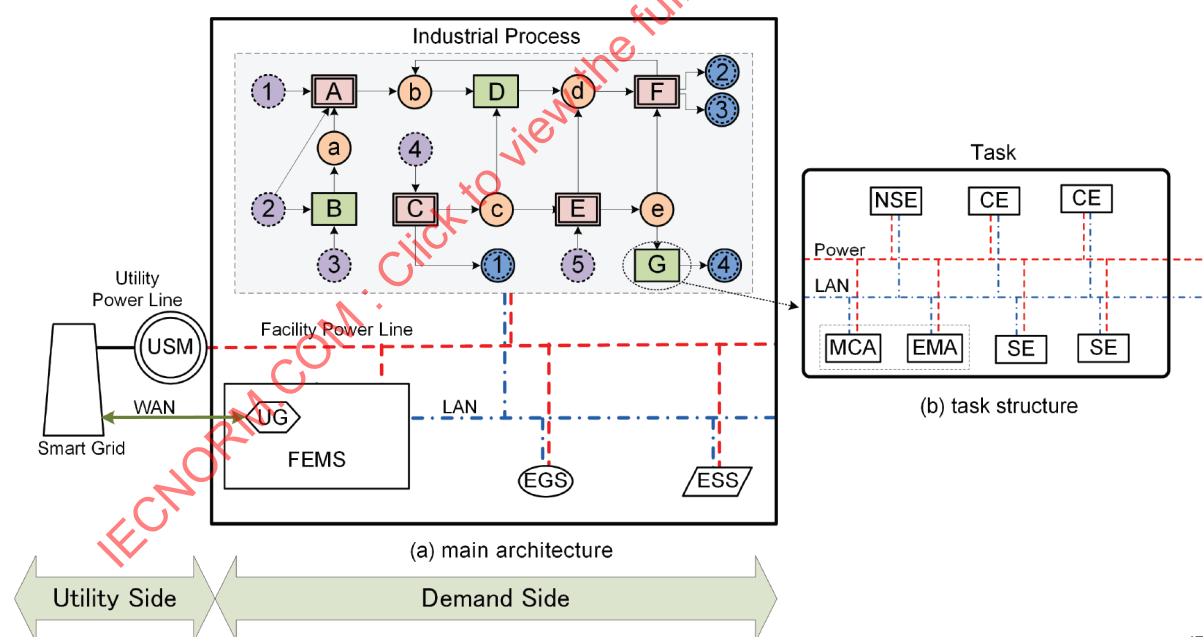


Figure 6 – Model architecture

5.2.2.3.2 Main architecture

Figure 6(a) represents the main architecture which is divided into the smart grid (utility side) and industrial facility (demand side). In general, the smart grid reads the smart meter while the utility gateway (part of the FEMS) is in charge of smart grid communication. Communications within the industrial facility, represented by the LAN in Figure 6, may represent multiple networks within the facility as described in Figure 4.

The industrial facility has two kinds of interactions with the smart grid. The first is the energy transmission and the second is the informational communications. Although there is some form of counterpart player for each interaction, the model does not make provision for differences and thus acts as a monolithic external smart grid player.

The industrial facilities consist of FEMS, EGS (optional), ESS (optional), LAN, facility power line, and industrial process. The FEMS receives the energy price information from the smart grid and schedules the energy demand of the industrial facilities according to preinstalled energy management algorithms and strategies. The EGS is able to generate energy using industrial waste heat, solar power, wind power, or other sources. The ESS can store energy from the facility power line and from the EGS. Both the EGS and ESS can serve as the energy sources for all or part of the industrial facilities. The LAN enables the exchange of messages among the elements in industrial facilities and the facility power line distributes energy to each element.

The industrial process part represents the topology of industrial facilities which produces final products from a series of raw materials and/or purchased semi-finished products with each task representing a group of processing operations. For example, feeds '2' and '3' are processed by task 'B' creating intermediate status 'a' which is further processed by non-schedulable processing task 'A' on route to becoming final products '2' and '3'.

Within the industrial process part, the energy demand of some tasks needs to be satisfied immediately (so called non-schedulable tasks). Otherwise, the reliability of industrial process may be affected or the product quality cannot be satisfied, etc. The energy demand of the other tasks can be scheduled among multiple operating modes (so called schedulable tasks).

EGS, ESS, and schedulable tasks are potential candidates of energy management in industrial facilities to balance the demand side and supply side to reduce the probability of an energy mismatch.

5.2.2.3.3 Task structure

Figure 6(b) represents the task structure. Each task is composed of MCA, EMA, power source switch, and industrial processing equipment. For local tasks, MCA (client process manager) monitors and controls processing with the objective to satisfy industrial requirements such as reliability, safety, product quality and others. EMA is the energy manager of a local task, which monitors energy consumption and manages the electric load of the task. Industrial process equipment can be classified as non-shiftable equipment (NSE), controllable equipment (CE) and shiftable equipment (SE). Energy demand of NSE needs to be satisfied immediately because an energy shortage for NSE may cause equipment damage, affect product quality, etc. CE support multiple operating levels with each level having different energy demand and operating characteristics. The energy demand of SE can be satisfied at an earlier or later time. (CE and SE only exist in schedulable tasks.)

For schedulable tasks, EMA categorizes multiple operating modes for the local task with each mode having a different production rate and energy demand, which facilitates energy management in industrial facilities.

5.2.2.4 Approaches to industrial facility energy management

In order to implement energy management in industrial facilities, the smart grid announces energy prices that reflect the energy supply and demand relationships at pre-specified time intervals (for example, intervals between 30 min and 60 min). Low energy prices would be announced when the energy demand is low in order to encourage energy use, while high energy prices would be announced when the energy demand is high in order to discourage energy use.

After receiving the energy price for a stage, the FEMS of industrial facilities manages the energy demand based on preinstalled energy management algorithms and strategies through two approaches.

- a) Approach 1: FEMS determines the operating mode for schedulable tasks in that stage.

Under the premise of satisfying the requirements of industrial facilities (such as market demand, reliability, safety, resource storage, etc.), a low energy price encourages the FEMS to command schedulable tasks to operate in a mode that has high energy demand with fast production rates, while a high energy price encourages the FEMS to command schedulable tasks to operate in a mode that has low energy demand with slow production rate. As a result, the energy demand of industrial facilities is increased when the energy price is low and is decreased when the energy price becomes high.

- b) Approach 2: FEMS commands the ESS to store energy from the smart grid or commands the ESS and EGS to supply energy to processing tasks.

A low energy price encourages the FEMS to command the ESS to store energy from the smart grid and command the processing tasks to use the smart grid as their energy source, which increases the energy demand. A high energy price, on the other hand, encourages the FEMS to command the ESS and EGS to supply energy to some or all of the processing tasks, which decreases the energy demand of the industrial facility.

In summary, the energy demand of industrial facilities is shifted from peak-demand periods to off-peak demand periods using energy management approaches; this contributes to balancing the energy supply side and demand side.

In addition, depending with the situations of energy supply / demand balance between the smart grid and the FEMS, they implement measures agreed previously among them.

Practical approaches are described as flows:

- a) Approach 3: FEMS (which consumes energy purchased from the SG) increases (decreases) energy consumption to achieve balance between energy supply and demand.
- b) Approach 4: FEMS (which supplies energy to the SG) increases (decreases) energy supply to achieve balance between energy supply and demand.

Annex C provides an application example for the demand response energy management model based on steel industrial facilities.

5.3 System interface mode between facility and smart grid

Figure 7 highlights the interface for information between the FEMS within the facility and the smart grid. The utility gateway may include security functions, for example using a firewall, to protect the FEMS from external attack. The FEMS is also shown connected to the facility smart meter (FSM), and in practice there may be more than one meter, and the connections to them are internal to the facility and out of scope of this document.

This document represents the various entities and actors within the smart grid as a single actor called smart grid. Thus, Figure 7 depicts the FSM but not utility smart meter (USM), which exists as a part of the smart grid.

Despite the FEMS being presented as a single box in Figure 7, this should not imply that it is a single appliance. The FEMS represents a set of related functions where some tasks may be classified as level 4 functions while others may be associated with lower levels (as represented in Figure 4).

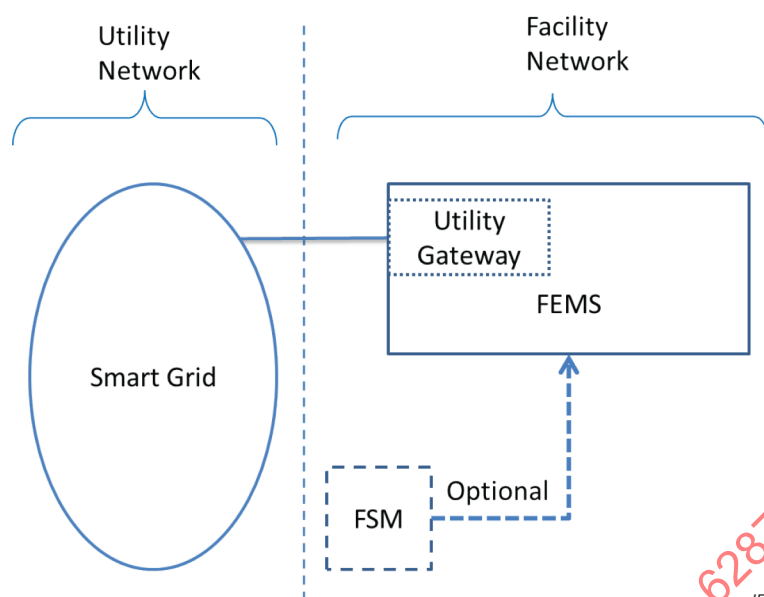


Figure 7 – Network architecture model

FEMS encompasses the functions needed for the management of facility energy use. The internal operation of the FEMS, and the interfaces between FEMS and facility internal equipment, is out of scope of this document.

5.4 Security requirements

Cyber-attacks represent significant threats to industrial facilities where security breaches can place equipment, production quality, system reliability and facility safety at risk. Firewalls, software and other security protocols shall provide adequate security assurance levels by preventing the propagation of cyber-attacks within the FEMS.

Industrial security shares with smart grid security the primary aim of ensuring the protection of people, the environment and physical assets, and ensuring uninterrupted safe operation. This emphasis is unlike information and communications technology (ICT) security, where the protection of information is typically the most important. This different emphasis significantly affects security strategies. Industrial security places "integrity and authentication" and "fail-safe" above ensuring the confidentiality of information.

Security requirements for the FEMS shall be compliant to the IEC 62443 series.

The security model shall be based on a graded approach. The interfaces shall be assigned to security degrees according to their importance to system security and characteristics. System security should adopt a multi layered approach rather than placing reliance on a single security measure.

The utility gateway shall be evaluated to ensure that it has the highest security assurance level since it is connected to an untrusted external network.

Accordingly, all utility gateway communication shall be evaluated in the FEMS design phase to ensure that all external communications are adequately protected against security breaches.

More details are provided in Annex D.

5.5 Safety requirements

The operation of the interface shall not at any time impair the safe operation of the facility. The implementation of suitable safety instrumented systems, and other required safety measures, are outside the scope of this document (for further information refer to IEC 61508 [2] and any related sector specific standards such as IEC 61511 [1]).

The FEMS shall be responsible for ensuring that all information received from the smart grid is validated against permissible values and that any information that may affect the operation of facility resources is properly validated and authorized by facility.

5.6 Communication requirements

5.6.1 General

Communication between the FEMS and the external grid operator is expected to be supported using the global internet, using secure virtual private channels or other suitable security measures. Compatibility with existing common means for communications, and means used for communications with the smart grid, will be essential. Since the performance of an internet-based communications infrastructure cannot be guaranteed, the messaging protocols shall accommodate situations where message may be excessively delayed or lost. The communications requirements outlined in 5.6 shall be met by the communications network.

5.6.2 Use of common communications technology

Communications to support the facility interface to the smart grid should not require the deployment of additional technology unless suitable technology does not already exist. Thus, existing Internet connections and firewall technology should be capable of being used if desired by the facility. This implies that the data transport protocols used by the interface should conform to common standard protocols and security protocols.

5.6.3 Communication security requirements

The communications technology shall meet all of the security requirements identified in 5.4 including support for the secure communications standards needed to meet these security requirements.

To prevent the cyber-attacks, unauthorized communications from and/or to utility gateway shall be discarded. It means related device shall be predefined and other communications shall be discarded.

5.6.4 Network availability

High network availability is required to ensure that the communications needed to manage manufacturing processes, costs and respond to energy emergencies, is not interrupted or delayed. Any communications failure shall be addressed promptly. Consideration should be given to using redundant links if adequate availability cannot be obtained using a single link. The exchange of periodic messages over the link(s) will ensure that communications failures are detected in a reasonable time.

5.6.5 Time synchronization

A common understanding of time is essential for the correct interpretation of cost and planning information. Messages containing time stamps may also be used for audit purposes. Many facilities develop their own understanding of time based on GPS or other precision time sources.

In some cases, the communications network may be used to maintain consistency within a reasonable range based on local agreement between the facility and the smart grid.

The security issues of the time synchronization approach selected should be assessed. For example, if network synchronization uses common protocols such as unsecured NTP, the facility should ensure that externally initiated attacks on the facility's understanding of time do not impact safety and ongoing operations.

5.7 Audit logging requirements

Many facilities will require that all communications with the smart grid be capable of being audited. Such auditing may be required to ensure that records are available to assist in the post-incident analysis of significant events, or for the purpose of ensuring that invoicing and billing functions accurately reflect purchases and sales of power.

For some arrangements, it may be necessary to ensure that such records can withstand scrutiny by third parties, or meet evidentiary requirements. Such record keeping may require that significant communications between the FEMS and the smart grid be time-stamped and signed, include non-repudiation attributes, or be copied to trusted third party entities.

5.8 Information requirements

5.8.1 General

Subclause 5.8 summarizes at a high level the information requirements for the messages identified in the use cases of Annex A. This assessment takes into account the ability of existing and planned standards to address the needs of industry. Many groups are developing such standards, and thus this assessment takes into account both existing and under development standards. Gaps are identified so that the needs of industry can be incorporated into future work.

Annex E addresses the solution examples for the required information introduced in 5.8.

5.8.2 Information attributes

Table 1 represents the expected information exchanged between smart grid and FEMS derived from the use cases in Annex A and Annex B. Facility internal messages, such as between FEMS and LOAD or FER, are outside the scope of this document. The smart grid internal messages are also out of scope of this document.

The columns in Table 1 are used as follows. "UC" refers to the facility-grid (FG) use cases which are fully explained in A.3.3 and B.2.2. "Interaction" refers to the specific interaction within the corresponding use case, as described in the correspondingly numbered paragraph of the detailed description within A.3.3 and B.2.2. For example, the first entry in Table 1 identifies interaction 3-4 of FG-100 which is explained in A.3.3.1.2.

Note that some of the interactions described in the use cases are internal to the facility or smart grid and do not represent interactions crossing the interface. The contents of these are a local matter and out of scope of this document. Thus, for example, the semantics and data of interactions 1-2 and 2-2 of FG-100 are not included in Table 1.

"Dir" indicates the direction of the data flow between the smart grid and facility energy management system. For example, SG > FEMS indicates that information flows from SG to FEMS. "Function" provides a general description for the interaction. "Freq." identifies the approximate frequency of the interaction, for example "week/month" indicates that a corresponding interaction might occur every week or month. "Urgency" identifies the approximate performance requirement, rated "low", "medium" or "high". These are relative measures where "low" indicates that delivery within several minutes is acceptable, while "high" implies that reliable delivery within about ten seconds is acceptable. "Semantic" represents the explanation of the interaction provided in A.3.3 and B.2.2. "Example of data transferred" provides a list of example information which is expected to be transferred by the corresponding interaction.

Table 1 – Required information

UC	Inter action	Dir	Function	Freq.	Urgency	Semantic	Example of data transferred
FG-100	3-4	SG > FEMS	SG provides requested energy records	week/month	low	Energy consumption, generation or other energy supply (e.g. as read from USM). Historical energy consumption, generation or other energy supply, along with billing and invoicing history. Optional forward energy pricing information for sale and potential purchase of energy or other energy services available (see also FG-300). Historical and forward predicted power quality information as available. Other information as agreed, e.g. weather information.	Information as offered by the SG may include for example: • energy consumption, generation or other energy service supply or use (e.g. as read from USM). • historical energy consumption, generation or other energy service supply or use, along with billing and invoicing history. • forward energy pricing information for sale and potential purchase of energy or other energy services available, including time of day, seasonal or other largely fixed (static) price lists (may overlap information provided using FG-300). • historical and forward predicted power quality information as available. • fixed (stable) characteristics of energy services made available to the Facility (e.g. SG ability to withstand rapid load changes). • historical and current environmental impact data corresponding to energy services. • other information as agreed, e.g. weather information.

UC	Inter action	Dir	Function	Freq.	Urgency	Semantic	Example of data transferred
FG-100	4-2	FEMS > SG	FEMS provides requested energy records	week/ month	low	Information as offered by the Facility may include: Energy consumption, generation or other energy supply (e.g. as read from FSM). Historical energy generation or other energy supply, along with invoicing history. Optional forward energy pricing information for sale of energy (generated by the Facility) or other energy services offered. Historical and forward predicted power quality information as available. Other information as agreed.	Information as offered by the Facility may include for example: - energy consumption, generation or other energy service supply or use (e.g. as read from FSM). - historical energy generation or other energy supply or use, along with invoicing history. - forward energy pricing information for sale of energy (generated by the Facility) or other energy services offered. - historical and forward predicted power quality information as available. - fixed (stable) characteristics of Facility consumption, generation or other energy service supply or use (e.g. load change characteristics of Facility equipment, performance characteristics of Facility generation equipment). - as needed, Facility largely static equipment and configuration information (e.g. to support the transfer of IEC 61970-301 [8] power grid model" information). - historical and current environmental impact data corresponding to energy services. - other information as agreed, e.g. local weather information.

UC	Inter action	Dir	Function	Freq.	Urgency	Semantic	Example of data transferred
FG-200	1-9	FEMS > SG	FEMS sends energy plan	day/ week	medium	Energy plan describes the consumption, generation, or any other energy services expected to be used during each pre-agreed interval during the planning period. Optionally, requested content of energy plan can be identified in advance between SG and FEMS.	Facility energy plan describes the planned consumption, generation, or any other energy services expected to be used or supplied during each pre-agreed interval for upcoming planning periods. This may include for example: - multiple plans. - each plan uniquely identified. - plans may cover differing planning periods. - plans may overlap (e.g. facility may not have a single plan active at any one time). - plans may be used to define maximum consumption (peak load) of Facility for upcoming period. - plans may be used to offer generation, storage or other energy services to be used at option of SG (e.g. emergency standby generation service or regulation service). - plans may need to include energy service characteristics (e.g. ramp-up, ramp-down) of intervals within the planning period if not previously characterized (e.g. using FG-100). - environmental impact data for energy services offered. - link to manual communications (e.g. reference point to allow manual communications between SG and Facility staff). - other information as agreed, e.g. to support SG energy planning.
FG-200	2-1	SG FEMS	SG responds to plan	In response	high	Optional confirmation or rejection of plan.	SG response to the energy plan may include for example: - acknowledgment of plan receipt. - request to modify the plan. - request to activate a plan (e.g. to accept offer to provide standby service). - environmental impact data for energy services to be provided. - link to manual communications.

UC	Interaction	Dir	Function	Freq.	Urgency	Semantic	Example of data transferred
FG-300	1-2	SG > FEMS	SG issues price, environmental and other schedules	day/week/month	medium	SG provides price schedules covering future period(s) which define the sale price of energy and if appropriate the purchase price of energy and any other energy services offered by the Facility. Formats may range from simple manually distributed fixed time-of-day sale prices for energy, to more detailed pricing distributed using this interface for specific intervals of future time.	SG provides price schedules covering future period(s) which may include for example: - the sale price of energy or other energy services offered by SG. - the offered purchase price of energy or other energy services offered by the Facility. - environmental impact data for energy services. - prices may range from simple manually distributed fixed time-of-day prices to more detailed prices for specific intervals of future time. - for larger Facilities where dynamic prices may be offered using FG-400, minimum and maximum prices may be indicated to allow Facility advanced planning.
FG-300	2-3	FEMS > SG	FEMS issues price, environmental and other schedules	day/week/month	medium	Optional FEMS provides equivalent information for the energy services it offers.	FEMS provides price schedules for the energy services it offers, which may include for example: - the offered sale price for the energy services offered by the Facility. - prices may range from simple manually distributed fixed time-of-day prices to more detailed prices for specific intervals of future time. - environmental impact data for energy services.
FG-400	1-2	SG > FEMS	SG issues price offer	minute/hour/day	high	SG provides price offer for energy service.	SG provides dynamic price offer for energy services, which may include for example: - short term price for energy over next pre-agreed interval(s) of time (such pricing allows SG to attempt to manage hourly load or availability of facility provided generation and storage using price incentives). - updated environmental impact data.
FG-400	3-1	FEMS > SG	FEMS responds to price offer	In response	high	FEMS replies to the offer. Contents of response is various.	FEMS response to the offer may include for example: acknowledgment of offer only (acceptance can be designated using FG-500 if required).

UC	Interaction	Dir	Function	Freq.	Urgency	Semantic	Example of data transferred
FG-500	1-4	FEMS > SG	FEMS sends energy update	minute/hour/day	high	FEMS provides new or updated energy plan to SG.	FEMS provides new or updated energy plan to SG, which may include for example: • indication of a change in energy service use or supply. • identification and specification of a new energy plan (see FG-200). • updated environmental impact data.
FG-500	2-1	SG > FEMS	SG responds to energy update	In response	high	SG response to energy update, e.g., accepting energy generation if it is offered in updated plan.	SG response to the updated energy plan may include for example: • acknowledges new energy plan. • rejection of new energy plan (e.g. if SG cannot provide requested increased energy or cannot tolerate load shed). • link to manual communications.
FG-600	1-2	SG > FEMS	SG sends risk notice	event-based	high	SG provides: – an indication of the probability of power interruption or power degradation – specific information about a rolling blackout or brownout along with scheduling information	SG sends a risk notice to the Facility which may include for example: • the identification of increased risk of a power interruption or power quality degradation along with its expected duration and reason. • specific information about a rolling blackout, brownout or other power quality deviation along with scheduling information. • weather or other information which may affect identified risk. • other information as pre-arranged, e.g. a request for emergency energy supply. • link to manual communications.
FG-600	3-1	FEMS > SG	FEMS responds to notice	In response	high	FEMS acknowledges the notice. – with offer to reduce limit load for risk period. – other response as previously agreed (e.g. request for delay).	FEMS response to the notice may include for example: • an offer to reduce or limit load for risk period. • other response as previously agreed, e.g. offer of emergency supply.

UC	Interaction	Dir	Function	Freq.	Urgency	Semantic	Example of data transferred
FG-710	1-1	SG > FEMS	SG notifies DR contract proposal	event-based	low	SG notifies the proposal of DR contract to the facility, including the incentive and other eligible conditions, e.g., minimum power range for adjustment, notification time, sustainable time, and penalty in case of failure of response.	DR contract proposal may include: - contract start date - contract end date - affordable month/week/day/time - notification time - sustainable duration of the operation - minimum power range (kW) for adjustment - type of baseline - type of incentive - type of penalty
FG-710	1-6	FEMS > SG	FEMS responds to SG	in response	low	FEMS responds to SG about the decision of the facility (i.e., agree with the proposal or not).	Response to SG may include the same data as indicated in the proposal.
FG-710	2-2	SG > FEMS	SG requests FEMS to change energy consumption	event-based	medium	SG requests FEMS to change volume of energy consumption for the requested time period.	The request may include: - event ID - starting date and time - duration of the operation - changing level (kW) of energy (increasing or decreasing) - baseline - incentive - penalty
FG-710	2-7	FEMS > SG	FEMS responds to SG	in response	medium	FEMS responds to SG regarding the decision (i.e., acceptance or rejection).	Response to SG may include the same data as indicated in the request.
FG-710	3-1	SG > FEMS	SG dispatches DR message	event-based	high	SG dispatches DR message to FEMS.	DR message may include: - event ID - starting date and time - duration of the operation - changing level (kW) of energy (increasing or decreasing) - baseline - incentive - penalty - data for real time report: - metered energy, - time stamp.

UC	Inter action	Dir	Function	Freq.	Urgency	Semantic	Example of data transferred
FG-710	4-2	SG > FEMS	SG notifies the ending of DR to FEMS	event-based	low	SG notifies the ending of DR event to FEMS and also informs FEMS of the actual quantity of energy adjustment and the corresponded reward.	Ending notice may include: • event ID • starting date and time • duration of the operation • operation result (success or failure) • compensation (reward or penalty) • report items: – metered energy, – time stamp.
FG-720	1-1	SG > FEMS	SG notifies FEMS of energy supply contract proposal	event-based	low	SG notifies the proposal of energy supply contract to the facility, including the incentive and other eligible conditions, e.g., minimum power range for adjustment, notification time, sustainable time, and penalty in case of failure of response.	Energy supply contract proposal may include: • contract start date • contract end date • affordable month/week/day/time • notification time • sustainable duration of the operation • minimum power range (kW) for adjustment • type of baseline • type of incentive • type of penalty
FG-720	1-6	FEMS > SG	FEMS responds to SG	in response	low	FEMS responds to SG about the decision of the facility (i.e., agree with the proposal or not).	Response to SG may include the same data as indicated in the proposal.
FG-720	2-2	SG > FEMS	SG requests FEMS to change volume of energy supply	event-based	medium	SG requests FEMS to change volume of energy supply for the requested time period.	The request may include: • event ID • starting date and time • duration of the operation • changing level (kW) of energy (increasing or decreasing) • baseline • incentive • penalty
FG-720	2-7	FEMS > SG	FEMS responds to SG	in response	medium	FEMS responds to SG regarding the decision (i.e., acceptance or rejection).	Response to SG may include the same data as indicated in the request.

UC	Interaction	Dir	Function	Freq.	Urgency	Semantic	Example of data transferred
FG-720	3-1	SG > FEMS	SG dispatches a supply change message	event-based	high	SG dispatches a message to FEMS to start increasing (decreasing) energy supply.	The message may include: • event ID • starting date and time • duration of the operation • changing level (kW) of energy (increasing or decreasing) • baseline • incentive • penalty • data for real time report: – metered energy, – time stamp
FG-720	4-2	SG > FEMS	SG notifies the ending of supply change to FEMS	event-based	low	SG notifies the ending of supply change event to FEMS and also informs FEMS of the actual quantity of energy adjustment and the corresponded reward.	Ending notice may include: • event ID • starting date and time • duration of the operation • operation result (success or failure) • compensation (reward or penalty) • report items: – metered energy, – time stamp.
FG-810	1-3	FEMS > SG	FEMS notifies SG of the proposal of energy purchase contract	event-based	low	FEMS notifies SG the proposal of energy purchase contract, including volume change options, e.g. some possible cases when purchasing energy volume needs to be increased or decreased to solve internal problem for certain time period.	The proposal may include: • contract start date • contract end date • notification time • sustainable duration of the operation • adjustment capacity (kW) of energy (increasing or decreasing).
FG-810	1-4	SG > FEMS	SG responds to FEMS	in response	low	SG responds to FEMS about the agreement with the proposal.	Response to FEMS may include same data as indicated in the proposal.
FG-810	2-4	FEMS > SG	FEMS requests SG to increase (or decrease) energy supply to facility	event-based	medium	FEMS dispatches a message to SG to increase (or decrease) specific volume of energy supply to facility for the demanding period with starting time and ending time.	The message may include: • event ID • starting date and time • duration of the operation • changing level (kW) of energy (increasing or decreasing).
FG-810	2-5	SG > FEMS	SG confirms the request	in response	medium	SG confirms the message and replies to FEMS with its possible operation.	Confirmation message may include the same data as indicated in the request.
FG-810	4-3	FEMS > SG	FEMS notifies SG the end of the requested energy supply adjustment	event-based	high	FEMS notifies SG the end of the requested energy supply to facility and way to resume back to an agreed operation defined in purchase contract.	Ending notice may include: • event ID • starting date and time • duration of the operation • changing level (kW) of energy (increasing or decreasing).

UC	Interaction	Dir	Function	Freq.	Urgency	Semantic	Example of data transferred
FG-810	4-4	SG > FEMS	SG confirms the end of the requested energy supply adjustment and informs facility of the actual quantity of adjusted energy supply	event-based	low	SG confirms the end of the requested energy supply operation and informs the actual volume of energy supply for the period, as well as corresponded compensation to be paid.	Confirmation by SG may include: • event ID • starting date and time • duration of the operation • report items: – metered energy, – time stamp. • Compensation.
FG-820	1-3	FEMS > SG	FEMS notifies SG the proposal of energy supply contract	event-based	low	FEMS notifies SG the proposal of energy supply contract, including volume change options, e.g. some possible cases when supplying energy volume needs to be increased or decreased to solve internal problem for certain time period.	The proposal may include: • contract start date • contract end date • notification time • sustainable duration of the operation • adjustment capacity (kW) of energy (increasing or decreasing).
FG-820	1-4	SG > FEMS	SG responds to FEMS	in response	low	SG responds to FEMS about the agreement with the proposal.	Response to FEMS may include same data as indicated in the proposal.
FG-820	2-4	FEMS > SG	FEMS requests SG to accept facility's increasing (or decreasing) energy supply	event-based	medium	FEMS dispatches a message to SG to accept that facility increases (or decreases) specific volume of energy supply to SG for the demanding period with starting time and ending time.	The message may include: • event ID • starting date and time • duration of the operation • changing level (kW) of energy (increasing or decreasing).
FG-820	2-5	SG > FEMS	SG confirms the request	in response	medium	SG confirms the message and replies to FEMS with its possible operation.	Confirmation message may include the same data as indicated in the request.
FG-820	4-3	FEMS > SG	FEMS notifies SG of the end of the requested energy supply	event-based	high	FEMS notifies SG the end of the requested energy supply to SG and way to resume back to an agreed operation defined in supply contract.	Ending notice may include: • event ID • starting date and time • duration of the operation • changing level (kW) of energy (increasing or decreasing).
FG-820	4-4	SG > FEMS	SG confirms the end of the requested energy supply adjustment and informs facility of the actual quantity of adjusted energy supply	event-based	low	SG confirms the end of the requested energy supply operation and informs the actual quantity of supplied volume for the period and the corresponded compensation to be paid.	FEMS dispatches a message which may include for example: • event ID • starting date and time • duration of the operation • report items: – metered energy, – time stamp. • compensation.

UC	Interaction	Dir	Function	Freq.	Urgency	Semantic	Example of data transferred
IBDR-1	1-2	SG > FEMS	SG notifies facility of incentive	event-based	low	SG notifies incentive and other eligible conditions to the facility, including the payment, minimum load reduction, frequency of activations, etc.	Incentive and eligible conditions issued by the SG may include: - contract start date - contract end date - affordable month/week/day/time - notification time - sustainable duration of the operation - adjustment capacity (kW) of energy (decreasing) - type of baseline - type of incentive
IBDR-1	1-7	FEMS > SG	FEMS responds to SG	In response	low	FEMS responds to SG regarding the acceptance or rejection of the offer.	Information responded by the facility may include same data as indicated in the incentive and conditions notice.
IBDR-1	1-8	SG > FEMS	SG issues incentive payments to facility	event-based	low	SG issues incentive payments to facility for enrolling in the DLC program and may sign a contract with the facility to confirm the transaction.	Contract signed between SG and facility may include: - contract start date - contract end date - affordable month/week/day/time - notification time - sustainable duration of the operation - adjustment capacity (kW) of energy (decreasing) - type of baseline - type of incentive
IBDR-1	2-2	SG > FEMS	SG informs the facility about DR signal	event-based	medium	SG informs the facility about the upcoming direct load control on short notice.	Notice of direct load control informed by SG may include: - event ID - starting date and time - duration of the operation - changing level (kW) of energy (decreasing) - baseline - incentive
IBDR-1	2-3	SG > Load	SG directly controls the load	event-based	high	SG directly controls the load to reduce the energy consumption below predefined threshold.	(Data for load control depends on application)
IBDR-1	3-2	SG > FEMS	SG notifies the ending of DR to FEMS	event-based	low	SG notifies the ending of DR event to FEMS.	Information notified by SG may include: - event ID - starting date and time - duration of the operation - operation results (success or failure) - report items: - metered energy, - time stamp.

UC	Interaction	Dir	Function	Freq.	Urgency	Semantic	Example of data transferred
IBDR-2	1-2	SG > FEMS	SG issues incentive and other eligible conditions	event-based	medium	SG issues incentive (e.g., \$/kW or \$/MW) and eligible conditions to the facility: minimum bid size, frequency of activations, notification time, sustainable time, capped number of times or hours per year, penalty in case of failure of response.	Incentive and eligible conditions issued by the SG may include: • contract start date • contract end date • affordable month/week/day/time • notification time • sustainable duration of the operation • adjustment capacity (kW) of energy (decreasing) • type of baseline • type of incentive • type of penalty
IBDR-2	1-7	FEMS > SG	FEMS responds to SG	In response	medium	FEMS responds to SG regarding the acceptance or rejection of the offer as well as the related load reduction options in case of acceptance.	Information responded by the facility may include the same data as indicated in the incentive and conditions notice.
IBDR-2	1-8	SG > FEMS	SG signs contract with facility	event-based	medium	SG may sign a contract with the facility to confirm the transaction, such a contract may specify the incentive size, quantity of curtailed load, duration, penalty size.	Contract signed between SG and facility may include: • contract start date • contract end date • affordable month/week/day/time • notification time • sustainable duration of the operation • adjustment capacity (kW) of energy (decreasing) • type of baseline • type of incentive • type of penalty
IBDR-2	2-2	SG > FEMS	SG sends DR signal	event-based	high	SG sends DR signal to the facility to curtail load according to the agreed load reduction options.	DR signal may include: • event ID • starting date and time • duration of the operation • changing level (kW) of energy (decreasing)
IBDR-2	2-3	FEMS > SG	FEMS responds to SG	In response	high	Facility may announce its inability of curtailing load to SG for this DR event (optional).	Information announced by facility may include: • inability of curtailing load • reason of failing to curtail load

UC	Interaction	Dir	Function	Freq.	Urgency	Semantic	Example of data transferred
IBDR-2	3-2	SG > FEMS	SG notifies the ending of DR to FEMS	event-based	low	SG notifies the ending of DR event to FEMS and also informs FEMS the actual quantity of curtailed load based on customer load baseline, and the corresponded reward or penalty in case of failure of response.	Information notified by SG may include: • event ID • starting date and time • duration of the operation • operation result (success or failure) • compensation (reward or penalty) • report items: – metered energy – time stamp.
IBDR-3	1-2	SG > FEMS	SG issues incentive and other eligible conditions	event-based	high	SG issues incentive (e.g., \$/kW or \$/MW) and eligible conditions to the facility: minimum load reduction, notification time, sustainable time.	Incentive and eligible conditions issued by the SG may include: • event ID • starting date and time • duration of the operation • changing level (kW) of energy (decreasing) • baseline • incentive
IBDR-3	1-7	FEMS > SG	FEMS responds to SG	In response	high	FEMS may optionally inform SG its willing load reduction upon the provided incentive.	• inability of curtailing load
IBDR-3	3-2	SG > FEMS	SG notifies the ending of DR to FEMS	event-based	low	SG notifies the ending of DR event to FEMS and also informs FEMS the actual quantity of curtailed load based on customer load baseline, and the corresponded reward.	Information notified by SG may include: • event ID • starting date and time • duration of the operation • operation result (success or failure) • compensation (reward) • report items: – metered energy, – time stamp.
IBDR-4	1-2	SG > FEMS	SG calls for bids	event-based	low	SG notifies facility to submit load reduction bids and also notifies the eligible conditions: minimum bid size, notification time, sustainable time, penalty in case of failure of response.	Eligible conditions issued by the SG may include: • contract start date • contract end date • affordable month/week/day/time • notification time • sustainable duration of the operation • adjustment capacity (kW) of energy (decreasing energy consumption) • type of baseline • type of penalty
IBDR-4	1-7	FEMS > SG	FEMS responds to SG	In response	low	FEMS submits its bids to SG in terms of a pair or pairs, i.e., (bid size, bid price).	Information responded by the facility may include the same data as indicated in the conditions for bids.

UC	Interaction	Dir	Function	Freq.	Urgency	Semantic	Example of data transferred
IBDR-4	2-2	SG > FEMS	SG notifies the accepted bid and signs contract with facility	event-based	low	SG clears the energy market using economic dispatch method and determines the winning bid, meanwhile, a contract can be made between two sides specifying the accepted bid size, interval of bid, penalty size.	Contract signed between SG and facility may include: • contract start date • contract end date • affordable month/week/day/time • notification time • sustainable duration of the operation • adjustment capacity (kW) of energy (decreasing energy consumption) • type of baseline • accepted bid price • type of penalty
IBDR-4	2-3	FEMS > SG	Facility sends acknowledgement to SG	In response	low	Optionally FEMS may send acknowledgement to SG indicating its confirmation of being a candidate DR resource	• acknowledgement of a candidate DR resource
IBDR-4	3-2	SG > FEMS	SG sends DR signal	event-based	high	SG sends DR signal to the facility to execute load reduction according to the accepted load reduction bid.	DR signal may include: • event ID • starting date and time • duration of the operation • changing level (kW) of energy (decreasing)
IBDR-4	3-3	FEMS > SG	FEMS responds to SG	In response	high	Facility may announce its inability of reducing load to SG for this DR event (optional).	• inability of curtailing load
IBDR-4	4-2	SG > FEMS	SG notifies the ending of DR to FEMS	event-based	low	SG notifies the ending of DR event to FEMS, and also informs FEMS the actual quantity of curtailed load based on customer load baseline, as well as the corresponded reward or penalty in case of failure of response.	Information notified by SG may include: • event ID • starting date and time • duration of the operation • operation result (success or failure) • compensation (reward or penalty) • report items: – metered energy, – time stamp.

UC	Interaction	Dir	Function	Freq.	Urgency	Semantic	Example of data transferred
IBDR-5	1-2	SG > FEMS	SG calls for capacity market program	event-based	low	SG notifies facility the eligible conditions for participating in capacity market program: minimum bid size (e.g., kW or MW), notification time, sustainable time, penalty in case of non-compliance.	Eligible conditions issued by the SG may include: - contract start date - contract end date - affordable month/week/day/time - notification time - sustainable duration of the operation - adjustment capacity (kW) of energy (decreasing energy consumption) - type of baseline - type of incentive - type of penalty
IBDR-5	1-7	FEMS > SG	FEMS submits pre-defined load reduction	In response	low	FEMS submits the pre-defined load reduction to SG as system capacity.	Information responded by the facility may include the same data as indicated in the conditions.
IBDR-5	2-2	SG > FEMS	SG provides payments and signs contract with facility	event-based	low	SG provides guaranteed payments to the facility, meanwhile a contract can be made between two sides specifying the agreed quantity of load reduction as system capacity, and penalty for non-compliance.	Contract signed between SG and facility may include: - contract start date - contract end date - affordable month/week/day/time - notification time - sustainable duration of the operation - adjustment capacity (kW) of energy (decreasing energy consumption) - type of baseline - guaranteed payments for being system capacity - type of incentive - type of penalty
IBDR-5	2-3	FEMS > SG	Facility sends acknowledgement to SG	In response	low	Optionally FEMS may send acknowledgement to SG indicating its confirmation of being a candidate DR resource for system capacity.	acknowledgement of a candidate DR resource
IBDR-5	3-2	SG > FEMS	SG notifies facility to reduce load	event-based	high	SG sends DR signal to the facility to execute load reduction as contracted previously.	DR signal may include: - event ID - starting date and time - duration of the operation - changing level (kW) of energy (decreasing)
IBDR-5	3-3	FEMS > SG	FEMS responds to SG	In response	high	Facility may announce its inability of reducing load to SG for this DR event (optional).	inability of curtailing load

UC	Interaction	Dir	Function	Freq.	Urgency	Semantic	Example of data transferred
IBDR-5	4-2	SG > FEMS	SG notifies the ending of DR to FEMS	event-based	low	SG notifies the ending of DR event to FEMS, and also informs FEMS the actual quantity of load reduction, as well as the corresponded payment or penalty for non-compliance.	Information notified by SG may include: • event ID • starting date and time • duration of the operation • operation result (success or failure) • compensation (reward or penalty) • report items: – metered energy, – time stamp.
IBDR-6	1-2	SG > FEMS	SG calls for ancillary service market program	event-based	low	SG notifies facility to submit ancillary service bids and also notifies the eligible conditions: qualification requirements for different types of ancillary services, minimum bid size, notification time, sustainable time, penalty in case of failure of response.	Eligible conditions for the bids issued by the SG may include: • contract start date • contract end date • affordable month/week/day/time • types of ancillary services • notification time • sustainable duration of the operation • adjustment capacity (kW) of energy (increasing or decreasing energy consumption) • type of baseline • type of penalty
IBDR-6	1-7	FEMS > SG	FEMS responds to SG	In response	low	FEMS submits ancillary service bids to SG in terms of a tuple, e.g., (ancillary service type, bid size, bid price).	Information responded by the facility may include same data as indicated in the conditions for the bids.
IBDR-6	2-2	SG > FEMS	SG notifies the accepted bid and signs contract with facility	event-based	low	SG clears the ancillary service market using some economic dispatch method and determines the winning ancillary service bids, meanwhile, a contract can be made between two sides specifying the accepted bid type, bid size, bid price and penalty.	Contract signed between SG and facility may include: • contract start date • contract end date • affordable month/week/day/time • types of ancillary services • notification time • sustainable duration of the operation • adjustment capacity (kW) of energy (increasing or decreasing energy consumption) • type of baseline • accepted bid price • type of penalty

UC	Interaction	Dir	Function	Freq.	Urgency	Semantic	Example of data transferred
IBDR-6	2-3	FEMS > SG	Facility sends acknowledgement to SG	In response	low	Optionally FEMS may send acknowledgement to SG indicating its confirmation of being a candidate DR resource for providing ancillary service.	acknowledgement of a candidate DR resource
IBDR-6	3-2	SG > FEMS	SG sends DR signal	event-based	high	SG sends DR signal to the facility to execute the load adjustment immediately or within the notification time depending on the ancillary service type.	DR signal may include: - event ID - starting date and time - duration of the operation - changing level (kW) of energy (increasing or decreasing)
IBDR-6	3-3	FEMS > SG	FEMS responds to SG	In response	high	Facility may announce its inability of adjusting load to SG for this DR event (optional).	inability of adjusting load
IBDR-6	4-2	SG > FEMS	SG notifies the ending of DR to FEMS	event-based	low	SG notifies the ending of DR event to FEMS, and also informs FEMS the actual quantity of adjusted load, as well as the corresponded reward or penalty in case of failure of response.	Information notified by SG may include: - event ID - starting date and time - duration of the operation - operation result (success or failure) - compensation (reward or penalty) - report items: - metered energy, - time stamp.

5.8.3 Example of data and data type

Table 2 shows examples of data, commonly used for the use cases FG-710, 720, 810, 820 and IBDR-1 to IBDR-6, which are requesting FEMS or SG to alter energy transactions, together with their general descriptions and data types.

Table 2 – Example of data and data type

Usage phase	Name of example data	Description	Data type	Reference use cases
Ahead of time	Contract start date	Starting date of the contract	Date (YYYYMMDD)	FG-710, 720, 810, 820 IBDR-1,2,4,5,6
	Contract end date	Ending date of the contract	Date (YYYYMMDD)	FG-710, 720, 810, 820 IBDR-1,2,4,5,6
	Affordable month/week/day/time	Specific period of time when requested adjustment is executable	Period of time	FG-710, 720 IBDR-1,2,4,5,6
	Notification time	Timing to send prior notice for operation change	Time (HHMM)	FG-710, 720, 810, 820 IBDR-1,2,4,5,6
	Sustainable duration of the operation	Possible duration to continue the subject operation	Period of time	FG-710, 720, 810, 820 IBDR-1,2,4,5,6
	Adjustment capacity (kW) of energy (increasing or decreasing)	Acceptable range of energy adjustment	Value	FG-710, 720, 810, 820 IBDR-1,2,4,5,6
	Type of baseline	Applicable baselines agreed for the subject operation	String	FG-710, 720 IBDR-1,2,4,5,6
	Type of incentive	Applicable incentives agreed for the subject operation	String	FG-710, 720 IBDR-1,2,5
	Type of penalty	Applicable penalties agreed for the subject operation	String	FG-710, 720 IBDR-2,4,5,6
Intra-day	Event ID	Identifier of the specific operation	String	FG-710, 720, 810, 820 IBDR-1,2,3,4,5,6
	Starting date and time	Starting date and time of the subject operation	Date (YYYYMMDD)	FG-710, 720, 810, 820 IBDR-1,2,3,4,5,6
	Duration of the operation	Duration to continue the subject operation	Period of time	FG-710, 720, 810, 820 IBDR-1,2,3,4,5,6
	Changing level (kW) of energy (increasing or decreasing)	Requested range of energy level change	Value	FG-710, 720, 810, 820 IBDR-1,2,3,4,5,6
	Baseline	Specific baseline for the subject operation	Value and/or string	FG-710, 720 IBDR-1,3
	Incentive	Specific incentive for the subject operation	Value and/or string	FG-710, 720 IBDR-1,3
	Penalty	Specific penalty for the subject operation	Value and/or string	FG-710, 720
	Data for real time report: metered energy	Measured energy data to be reported on real time basis	Value	FG-710, 720
	Data for real time report: time stamp	Time of energy data measurement to be reported on real time basis	Date time (YYYYMMDDHHMM)	FG-710, 720
	Operation result (success or failure)	Result of the subject operation	String	FG-710, 720 IBDR-1,2,3,4,5,6
	Compensation (reward or penalty)	Result of commercial deal based on the subject operation result	Value and/or string	FG-710, 720, 810, 820 IBDR-2,3,4,5,6

Usage phase	Name of example data	Description	Data type	Reference use cases
	Report items: metered energy	Measured energy data to be used for the final report	Value	FG-710, 720, 810, 820 IBDR-1,2,3,4,5,6
	Report items: time stamp	Time of energy data measurement to be used for the final report	Date time (YYYYMMDDHHMM)	FG-710, 720, 810, 820 IBDR-1,2,3,4,5,6

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Annex A (normative)

User stories and use cases

A.1 General

Industrial facilities have requirements for such communications which exceed, for example, the needs of home and building automation applications. These differences can be summarized as follows:

- a) Many industries have significant options for production scheduling given sufficient notice, but they can seldom respond to unplanned energy shortages by simply reducing their short term demand across the board. Unlike typical consumer applications where loads can be reduced, for example by acting on heating, ventilation, cooling and lighting, it is often critical that energy supply be kept in planned conditions once industrial production has started to ensure that production quality, facility safety and security are maintained. Some types or phases of production, once started, cannot be stopped immediately without damage to equipment. Thus, the criteria used to respond to unplanned demand events and energy fluctuations differ from those that can be used for home and building automation. The consequences of unplanned changes are factored into operations and into the design of the industrial facility itself.
- b) Some industrial facilities can postpone or reduce production at times of predicted energy shortage if given sufficient notice. Industrial facilities can be designed to adjust the production quantity, e.g. through parallelism, and the scheduling of activities across shifts. Industrial facilities could choose to reduce production if the current energy cost makes the incremental cost of production exceed the incremental product's value. Industry could choose to operate energy intensive operations during periods when energy costs are low. Simple time-of-day pricing would not always provide the flexibility needed to allow full exploitation of the scheduling possible. The time scales over which such negotiations and commitments to energy supply would be made will typically vary between industries.
- c) Many larger industries have significant internal energy generation and/or storage capabilities. A facility with in-house hydroelectric generation could draw energy from the smart grid during off-peak times and use the corresponding saved hydroelectric power to supply energy to the smart grid at peak times, thus providing the equivalent of pumped energy storage. Facilities with co-generation facilities could also assist the smart grid in meeting normal and emergency energy demands. These situations can only be addressed if the smart grid operator and industry can dynamically negotiate and plan such arrangements on a short-term basis.

To implement such applications, industry will require an interface to smart grid which provides sophisticated strategic planning and, in the future, negotiation capabilities along with the tactical communications needed to support agreed day-to-day and second-by-second power transfers.

A.2 User stories

The high level facility user stories (FUS) applicable to industrial facilities are summarized in Table A.1. Utility user stories (UUS) applicable from the smart grid perspective are summarized in Table A.2.

Table A.1 – Facility user stories: facility operation view points

Facility user story ID	Description
1	Facility energy planner receives information, including current and future pricing information, from the smart grid to use as input to facility energy planning and scheduling. NOTE 1 Such advanced pricing information may involve price ranges with final pricing only available nearer to the time of consumption or supply.
2	Production planner develops the production plan based on production requirements, cost and availability of input materials, equipment, labour, energy, etc. The planner designs production plan and schedule to minimize costs. The planner may provide resulting energy plan and schedule to the smart grid operator. For larger facilities, and in the future if supported, the facility may negotiate energy use and supply with the smart grid operator, include agreements on price (or range of pricing) and quality/performance during planned and identified production time intervals.
3	Production planner monitors current production and unit/equipment/labour status in the facility, while facility energy planner monitors pricing updates from the smart grid. Those planners modify their plans as needed and as possible to address significant changes from originally identified input conditions. The production planner will likely be limited in their ability to reschedule production once production has begun.
4	FEMS receives <i>forward</i> incentive information from the smart grid operator for encouraging the facility to participate in a certain program. Facility energy planner assesses the incentive together with production planner, and makes a decision to join the program or not.
5	Facility energy planner may request the smart grid to alter grid side's energy supply or purchase plan to the facility for the limited period of time in case of emergency.
6	Facility energy operator monitors facility operation and responds to deviations from planned operations; including deviations from planned energy use or generation. For example, should energy demand exceed planned demand, the operator might increase internal generation, use internal storage (battery) resources, or request additional supply from the smart grid. If generation exceeds that planned, the operator might offer additional generation to the smart grid, through facility energy planner, or divert the excess to local storage. Meanwhile, production operator provides sufficient responses to these deviations to ensure continued safe operation of the facility, to avoid damage to equipment and to avoid reductions in product quality.
7	FEMS receives <i>intra-day</i> notification from the smart grid operator regarding energy shortfalls, energy excess or system contingencies, upon the notification, the facility energy operator should activate the load adjustment that has been contracted with the smart grid operator in advance.
8	Production operator and facility energy operator receive information from the smart grid operator regarding deviations from planned energy supply or use arrangements. For example, those operators need to be informed of rolling blackout and/or risk of blackout from the smart grid so that changes to operation procedure and/or control strategies can be made to avoid any damage in production.
9	FEMS receives energy consumption and supply measurements from FSM or utility company operator and final contract pricing information, for the purpose of accumulating cost information for utility bill reconciliation and for the generation of invoices (if needed) for supplied power.
10	FEMS receives measurements of actual load adjustment and final incentive payments (or penalty) from the smart grid operator after a grid event terminates.
11	Quality assurance department wants to have energy related information per product (e.g. specific energy consumption and some other attributes), and provide it as energy foot print to users when supply chain management requests.
12	Facility accumulates records of all significant transactions and information to allow post-incident analysis, billing discrepancy audits, and to provide historical performance information in support of future production and operations planning. These records may be needed to meet evidence requirements for post-incident audits or billing discrepancy audits.

Table A.2 – Utility user stories: utility operation view points

Utility user story ID	Description
1	Utility-side operation receives information from facility regarding availability of load shedding, generation and storage over future time periods. Information may include ramp-up and ramp-down characteristics, cost/pricing information, emergency commitments, etc. This information may be used by the smart grid-side operator to plan future operations.
2	Utility-side operation receives from FEMS forward predictions of energy consumption and energy supply (as appropriate). Smart grid requires option to request changes to these plans to FEMS.
3	Smart grid operator may request industrial facility to alter the facility's energy consumption or supply plan to the grid for the limited period of time in case of emergency.

A.3 Use cases

A.3.1 Use case analysis

This Clause A.3 derives specific facility-grid (FG) use cases based on the high level facility user stories (FUS) and utility user stories (UUS). These use cases will be used to evaluate candidate solutions (existing and under development standards capable of supporting the corresponding use cases).

All the use cases described below may not be applicable to all industrial facility arrangements. For example, facilities which only require access to past and/or future pricing and billing information for planning or bill reconciliation purposes would only need use case FG-100.

Each use case is summarized below.

- a) FG-100: Facility and smart grid obtain current and past energy information.

The facility obtains electronic access to current and past energy consumption, supply, billing and other available information from the smart grid. Similarly, the smart grid obtains current and past energy information as made available by the facility.

- b) FG-200: Facility provides energy consumption and supply plan to smart grid.

The facility defines its general forward (predicted) energy consumption and supply plan (facility energy plan) to the smart grid. This information will be useful to the smart grid operator to assist in longer term energy planning.

- c) FG-300: Smart grid provides stable (long term) price schedule to facility.

The smart grid provides pricing and related information to support facility development of daily or longer production plans. For similar customers, the SG might issue the same price schedule to many customers. Both selling and purchase (if appropriate) prices, along with coefficients of environmental impact, may also be provided.

- d) FG-400: Smart grid provides dynamic (short term) pricing to facility.

The smart grid issues short term pricing incentives near to the time of energy use or supply as an incentive for the facility to adjust its energy use or supply. The objective of the SG is to maintain balance between generation and supply near the time of use.

- e) FG-500: Facility informs smart grid about upcoming consumption and supply.

The facility provides more timely information than in use case FG-200 about its upcoming consumption and supply, including possible updates to any previous energy plans.

- f) FG-600: Smart grid informs facility of blackout notice.

The smart grid predicts the risk of blackout, brownout, or other abnormal power situation and informs the facility about any mitigation plans which will impact the facility. This will allow the facility to respond by taking the measures necessary to protect the facility, its staff and any ongoing production.

g) FG-700: Smart grid requests facility to alter consumption or supply

FG-700 is a series of use cases that the SG requests the facility to change amount of energy supply or consumption, based on up-to-date energy supply plan of the SG.

h) FG-800: Facility requests smart grid to alter consumption or supply

FG-800 is a series of use cases that the facility requests the SG to change amount of energy supply or consumption, based on up-to-date energy related operation plan of the facility.

The dependency between user stories and use cases is shown in Table A.3.

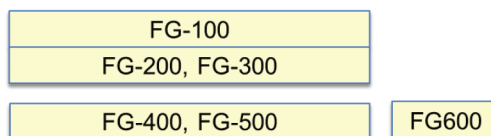
Table A.3 – Dependency between user stories and use cases

User story	FG-100	FG-200	FG-300	FG-400	FG-500	FG-600	FG-710 FG-720	FG-810 FG-820
FUS1	x		x					
FUS2		x						
FUS3			x	x				
FUS4				x		x	x	
FUS5								x
FUS6				x	x	x		x
FUS7				x		x	x	
FUS8						x		
FUS9	x							
FUS10						x	x	
FUS11	x		x					
FUS12	x							
UUS1	x		x					
UUS2		x		x	x		x	
UUS3							x	

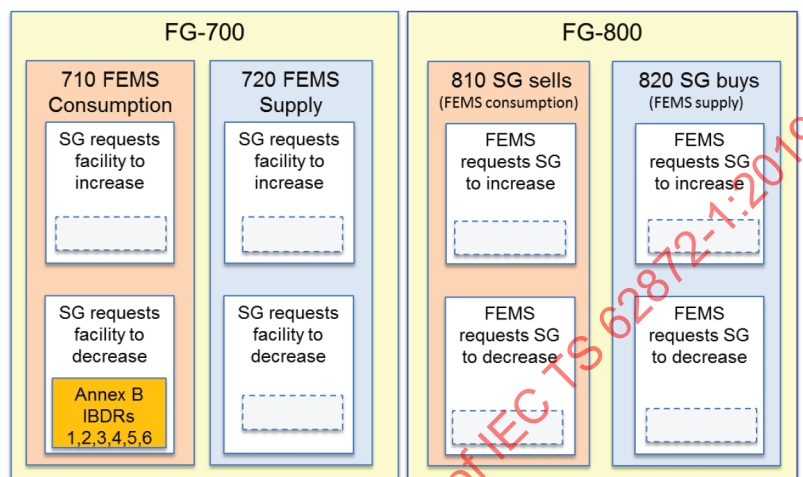
Figure A.1 describes the variations and relations among different use cases.

Use case variations and relations

Day to day
information sharing
not asking to alter
energy transactions



When situation
happens....
requesting to alter
energy transaction



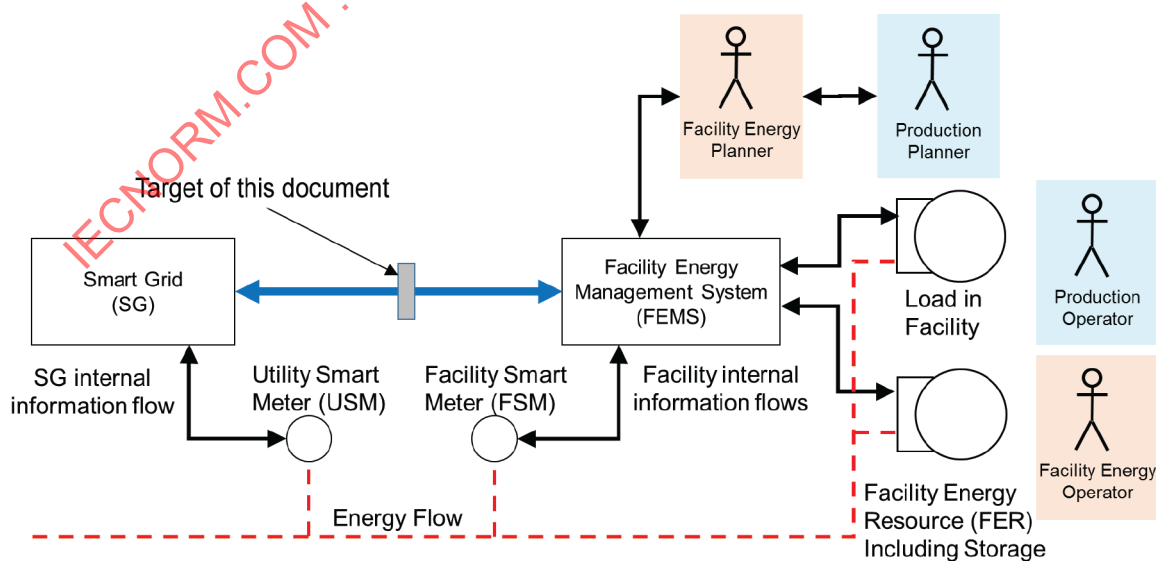
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Figure A.1 – Use case overview

A.3.2 Actor names and roles

Figure A.2, Figure A.3 and Table A.4 describe the actors/stakeholders and their relationship. In Figure A.2, the shadowed rectangle represents the interface between the smart grid and the FEMS, the main focus of this document. The dotted red and blue lines in the diagram represent the flow of energy and information respectively.

The balance of this Annex A provides a more detailed description of each of the use cases.



IEC

Figure A.2 – Generic communication diagram between the smart grid and the FEMS

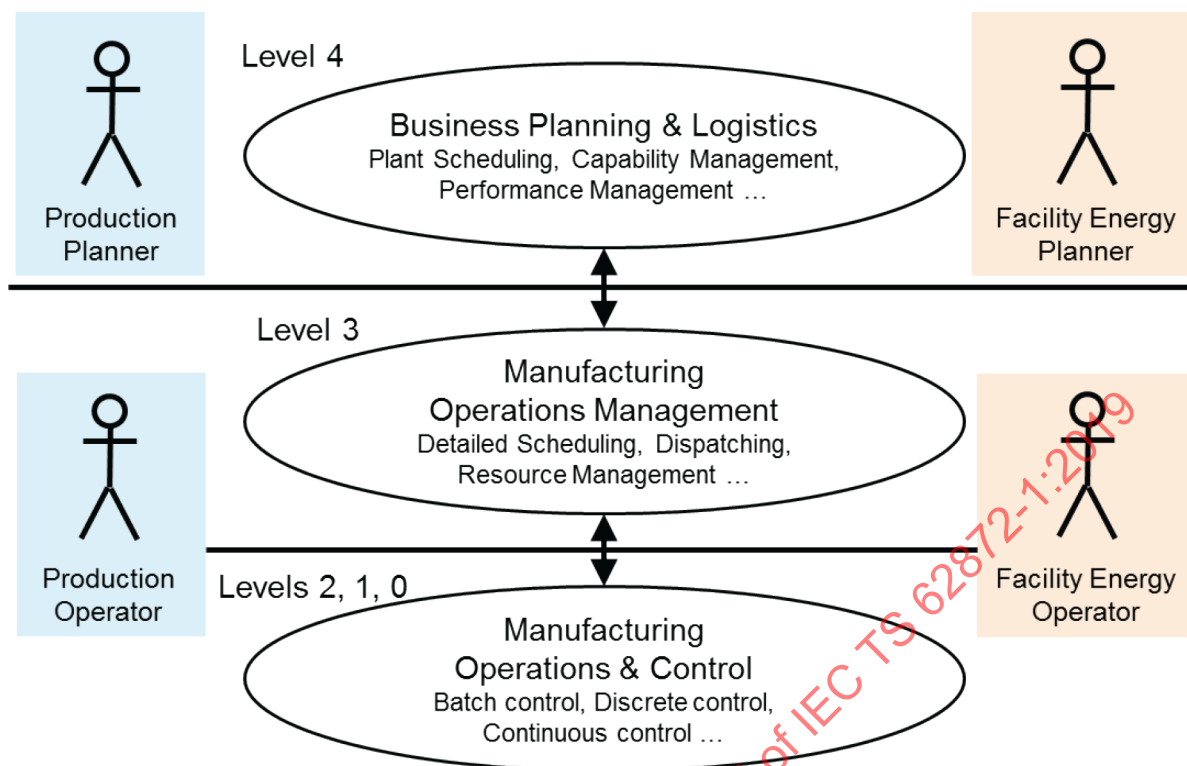


Figure A.3 – Actors in role hierarchy (IEC 62264-1)

Table A.4 – Actors and roles

Actor	Role
Facility energy management system (FEMS)	FEMS is any device/software or group of them installed in the industrial facility which provides the functions of energy management, control and planning in conjunction with responsible facility management (see production planner and operations manager, below). The FEMS functions are accomplished by one or more parts of an integrated facility automation control and enterprise system which is modelled in this document according to the IEC 62264-1 standard. This actor can communicate with all of the other actors.
Facility energy planner	This is an entity responsible for the advanced planning of facility energy use, storage and generation, taking into account the requirements of future production and the overall operation of the facility. The facility energy planner is responsible for defining the overall future energy plan for the facility, to include both the energy requirements of production and the overall needs and capabilities of the facility to generate, store, and consume energy. Plans developed by the facility energy planner will typically be made at least a day prior to intended use. The facility energy planner will assemble the overall energy plan based on the individual plans developed by production planners and the non-production requirements and capabilities of the facility.
Production planner	This is an entity responsible for developing, monitoring and modifying the production plan based on facility requirements and the availability of inputs. Example production constraints are the availability of input materials, production equipment, labour, energy, etc. The production planner designs the plan to minimize the costs of production.
Facility energy operator	This is an entity responsible for the minute by minute supply of energy to support current production and current facility operation. The facility energy operator monitors facility energy use, generation and storage, and makes adjustments in response to changes related to shifting energy supplies, material disruptions, and equipment breakdowns.
Production operator	This is an entity responsible for the minute by minute use of energy to carry out production plans, and authorized to respond to real-time changes based on feed-back from the process and other internal or external events. The production plan is given by the production planner.
Smart grid (SG)	External-to-facility electrical grid actor (smart grid market role) which interacts with FEMS. This actor is used to represent a range of potential external entities, including an electrical grid operator, independent (electrical) system operator, energy aggregator, etc. This actor is shown interacting with the FEMS and the smart grid owned smart meter.
Utility smart meter (USM)	Device which measures energy consumption or generation per time tariff and provides this information to utility company. Since this information may be used for billing purposes, its operation and metrological accuracy is normally subject to regulatory oversight. Secure communications with this device are provided by the smart grid. Read-only access to this information may be provided to the facility, although typically this information is only available indirectly from the utility company itself.
Facility smart meter (FSM)	Device which measures energy consumption or generation per time and makes available the information of total power consumption and generation in the facility to FEMS internally.
Load in facility	This actor represents all of the energy consumers in the facility. It consists of all of the loads managed by the FEMS from an energy perspective. This actor communicates with FEMS for the purpose of optimizing its operation.
Facility energy resource (FER)	This actor represents all of the energy generation and storage resources in the facility. These resources may be used to supply loads in the facility or might be used to supply power to the smart grid. Energy resources include combined heat and power (CHP) systems. These resources are managed by the FEMS from an energy perspective.

A.3.3 Use case descriptions

A.3.3.1 FG-100: Facility and smart grid obtain current and past energy information

A.3.3.1.1 General description

The facility obtains access to their current and past energy consumption, supply, billing and other available information records from the smart grid. The purpose of such access is, for example, to:

- permit access to the accumulation of historical data, and “energy footprints”, in support of future planning and quality assurance,
- assist in budgeting by providing access to power consumption and supply costs and revenues,
- permit FEMS to monitor on-going operations and detect deviations from plans,
- permit enterprise systems (via FEMS) to reconcile billing information, and
- support audit systems (if used).

The smart grid obtains access to current and past energy records, as made available by the facility. The purpose of such access is, for example, to:

- permit access to the accumulation of historical data, and “energy footprints”, as available and recorded by the facility, in support of SG future planning,
- assist in budgeting by providing, when available, access to power generation, storage and other service pricing as offered by the facility,
- permit SG access to FEMS monitoring data, for example power quality measurements made by the facility, and
- assist SG planning by providing access to the characteristics of power generation, storage, consumption and other relevant energy capabilities of the facility.

NOTE Some power utilities model the energy grid in support of forward energy planning. For larger facility interconnections, the characterization of significant facility energy loads and resources can be conveyed using this use case, for example by providing information in accordance with the common information model (CIM) IEC 61970-301 [8].

A.3.3.1.2 Detailed description

The numbered items in A.3.3.1.2 correspond to the similarly numbered items in the sequence diagram of Figure A.4. For example, item 1) describes the sequence identified with the number (1) in the figure and consisting of interactions (1-1) and (1-2) in the figure. For interactions which cross the facility and smart grid interface, their contents are summarized in Table A.5.

The first two items below describe assumed ongoing internal operations within the SG and facility which accumulate current and historical energy data that may be made available to the other party. Since these operations do not result in an interaction crossing the interface, they are not included in Table A.5.

- 1) Smart grid gathers and records billing and other data. How this is done depends upon the internal procedures of the SG and thus is out of scope of this document. However typically the SG will read utility smart meter(s) via their own networks (or using manual procedures), compute billing data, record performance, environmental and quality data, maintain customer billing accounts, and store this information for future use.

NOTE 1 In less typical situations, the SG could access a facility smart meter (FSM), for example when no USM is available; this is shown by the dotted line in Figure A.4. However, such a connection can represent an unacceptable security risk to the facility since it potentially bypasses the security protection provided by the FEMS. Possible approaches to allow access to FSM data by SG include the enforcement of unidirectional communications, the provision of a secure isolating conduit (tunnel) between the FSM and SG or the routing of this information via the FEMS (as indicated in item 4) of A.3.3.1.2). Except as discussed in item 4), such alternate communication is out of scope of this document.

- 2) The FEMS gathers and records various performance, invoicing and other data (as determined by the facility). The procedures used and the records maintained are determined by the facility and thus are out of scope of this document. However typically the facility will read data from FSM(s) and internal load, generation, storage and other equipment, potentially compute invoicing data for generation, storage or other services provided to the SG, record performance, environmental and quality data, and store this information for future use.

NOTE 2 In less typical situations, the facility could access a USM, for example when no FSM is available; this is shown by the dotted line in Figure A.4. While manual readings of the USM can be provided safely, any direct non-read-only electronic connection can represent an unacceptable security risk to the SG. Such alternate communication is out of scope of this document.

- 3) The production planner or other entity within the facility makes an internal request for energy data from the FEMS. The FEMS initiates a request to the SG for energy data and the SG responds with the requested data. The SG data is combined with any local energy data and returned to the requestor. Data provided by the SG may include a range of data, including environmental (e.g. CO₂) emission data. The solution identified to support this transfer needs to be flexible enough to meet current and future needs. A preliminary identification of the kinds of information to be supported is provided in Table A.5.

The language “FEMS initiates” used here does imply that the SG shall respond to externally initiated communications. Due to security concerns both the SG and FEMS may prefer to only initiate communications. Some candidate communications solutions utilize a common intermediate server infrastructure to manage interparty communications, e.g. using XMPP. In such configurations, the parties poll the infrastructure for messages and thus do not need to respond to communications initiated by others.

- 4) An entity internal to the SG initiates a request for energy data from the facility. This request is received by the FEMS and the FEMS responds with the requested available data. Typical information provided might be measurements taken by FSM(s) or other quality and performance measuring devices, invoice data for services sold to the SG, the characterization of facility equipment, or other information previously agreed-to. This data provided by the FEMS may include a range of data, and the solution identified for this case needs to be flexible enough to meet current and future needs.

The language “FEMS responds” used here does imply that the facility shall respond directly to externally initiated communications. As previously said, solutions employing an intermediate server infrastructure are available.

The above analysis indicates that a request/reply protocol solution, capable of being initiated by either party, and having sufficient flexibility to convey an extensible range of “energy” data could meet the requirement of this FG-100 use case.

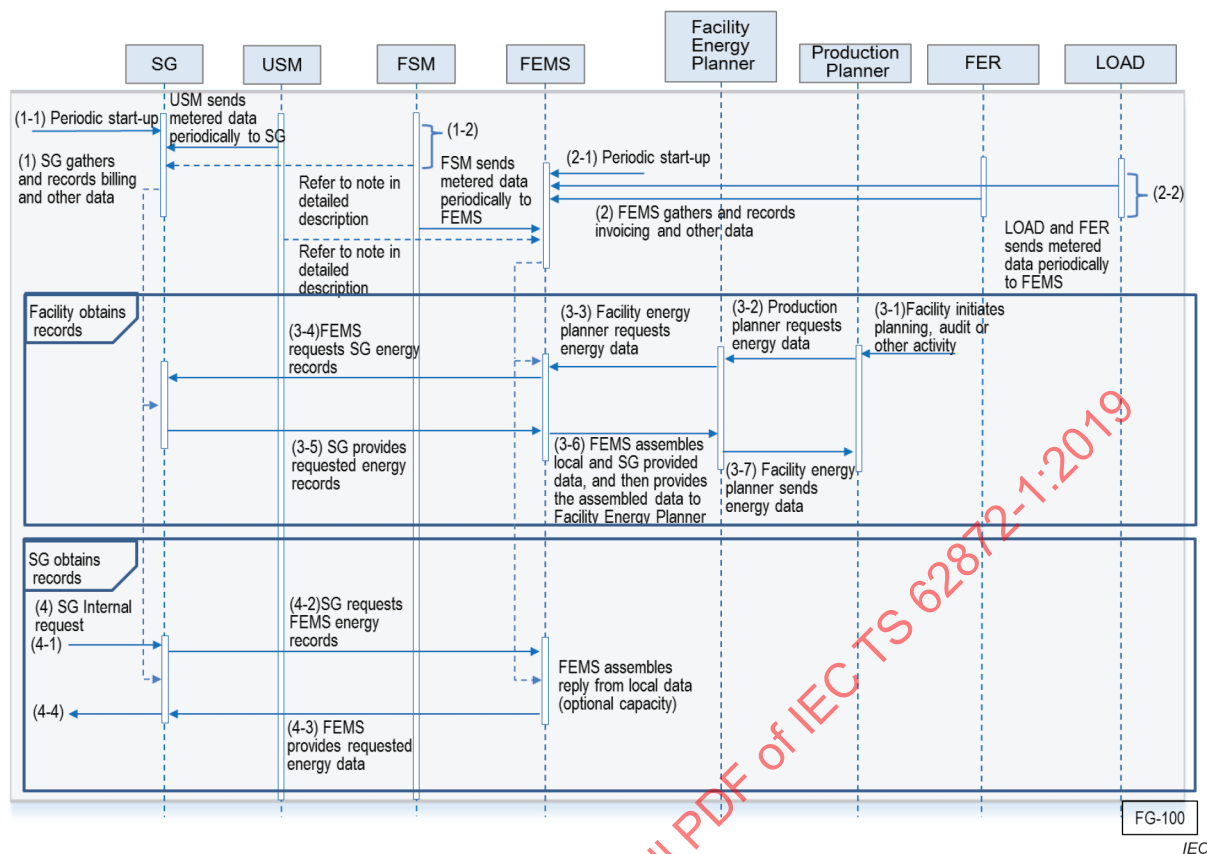


Figure A.4 – Sequence diagram for FG-100

Table A.5 – Exchanged information in FG-100

Interaction	From > To	Function	Semantics
3-4	SG > FEMS	SG provides requested energy records	Current energy consumption, generation or other energy supply (e.g. as read from USM). Historical energy consumption, generation or other energy supply, along with billing and invoicing history. Optional forward energy pricing information for sale and potential purchase of energy or other energy services available (see also FG-300). Historical and forward predicted power quality information as available. Other information as agreed, e.g. weather information.
4-2	FEMS > SG	FEMS provides requested energy records	Information as offered by the facility may include: Current energy consumption, generation or other energy supply (e.g. as read from FSM). Historical energy generation or other energy supply, along with invoicing history. Optional forward energy pricing information for sale of energy (generated by the facility) or other energy services offered. Historical and forward predicted power quality information as available. Other information as agreed.

A.3.3.2 FG-200: Facility provides energy consumption and supply plan to smart grid

A.3.3.2.1 General description

The facility provides the smart grid with its predicted consumption, supply, storage and other energy use or supply service plan (facility energy plan). This information may be derived from the upcoming facility production plan, for example based on historical knowledge of the energy consumption and excess generation associated with production, or the absence of production. The availability of unused, and thus available to SG, storage, generation, regulation or emergency energy supply services could also be indicated.

It may include facility generation/storage, load shedding/generation, ramp-up/ramp-down options, and other information as previously agreed. This use case addresses the provision of largely static information associated with the planned operation of the facility for an agreed future period of time. The period of time and the size of the discrete intervals used to characterize the energy plan would be as previously agreed, and aligned with internal facility and Smart Grid scheduling. As an example, FEMS might provide an upcoming prediction of energy use and energy service availability during each 15 minute interval over a future 5 day production period.

This provision of a general prediction of future energy consumption and supply is useful to the smart grid operator to assist in longer term strategic planning.

Some industrial facilities may not be capable of generating the energy forecasts needed for the advanced planning supported by this use case. For such situation where only the “near” real-time energy information is available, or for situations where real-time updates to FG-200 information are needed, use case FG-500 is defined.

A.3.3.2.2 Detailed description

The numbered items below correspond to the similarly numbered items in the sequence diagram of Figure A.5. For interactions which cross the facility and smart grid interface, their contents are summarized in Table A.6.

- 1) The production planner initiates the development of a production plan. And the facility energy planner initiates the development of facility energy plan based on the production plan. The extent to which production planning is carried out, and how this is done will depend upon the facility. In general, the production planner will identify production targets, assess input costs and the availability of resources, and establish a production plan for a future period of time. The cost of energy, and opportunities to sell generation and other energy services to the SG, may be factors in the design of the production plans and the facility energy plan.

The facility energy planner obtains energy and other historical information from the FEMS, including energy pricing information gathered as described in FG-300 or FG-100. The FEMS may provide tools to assist in the energy planning component of the production plan, to allow the planner to obtain a better understanding of the energy profiles of production systems.

The production planner develops and obtains internal facility approval of the production plan. The plan, or an abstract of the plan, is sent to the facility energy planner which extracts the plan's energy profile and sends this information to the SG through the FEMS.

The energy plan shall define the energy profile of the corresponding production plan. Such plans should also identify periods of non-production, so that the availability of unused facility energy resources can also be identified.

High level information to be included is summarized in Table A.6 and may include information and other availability data as needed to characterize loads, generation/storage, ramp-up/ramp-down and other requirements when they differ from previously established values (e.g. as per use case FG-100). The energy plan will cover the planned production period, identifying planned loads, available generation, or other energy services, during discrete intervals of time during the period. Depending upon the locality, these discrete

time intervals typically vary between 5 minutes and 15 minutes, but defining the interval is out of scope of this document.

- 2) Optionally the SG acknowledges the energy plan and sends a response to the FEMS, which in turn forwards a response to the facility energy planner. This optional information flow may be required for arrangements where the facility proposes in the energy plan a more complex energy arrangement for one or more intervals. For example, if the facility has no production scheduled, and has internal energy generation resources available, the SG may wish to explicitly accept an offer of standby generation in this time. The acceptance of such an offer could then be incorporated in the production planner's production plan. Refer also to FG-700 which might be used to support later acceptance of such offers.

More complex arrangements of this type are for further study. However, during the review of candidate standards, the flexibility of the candidate to support such extensions should be considered.

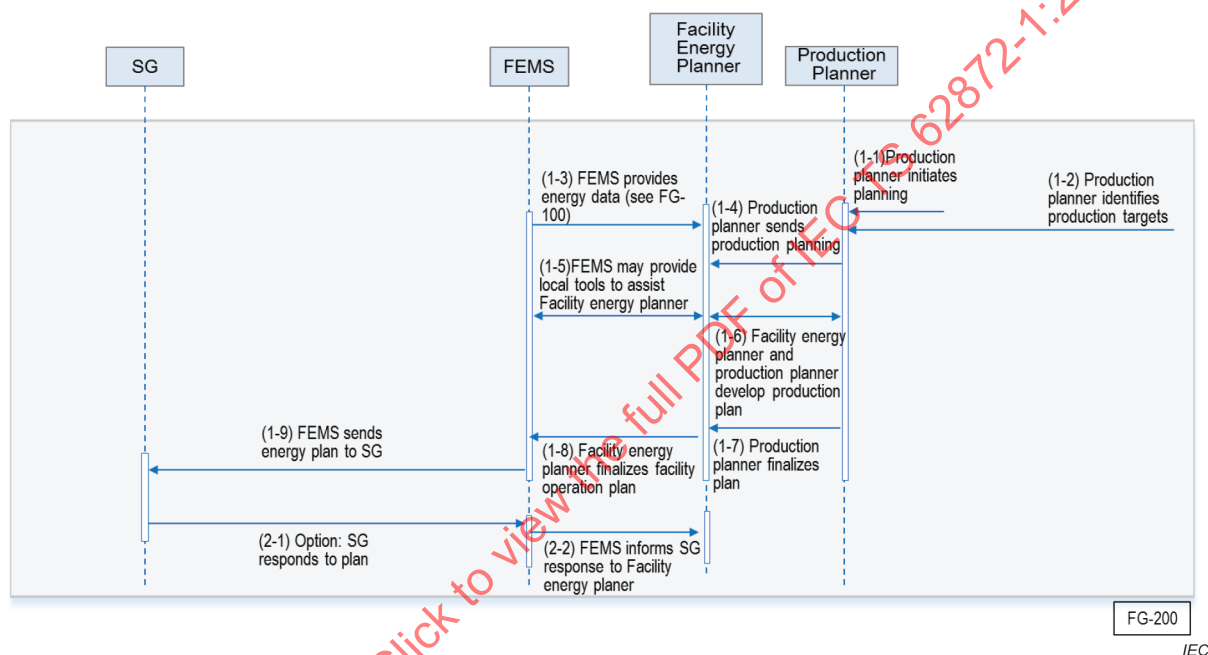


Figure A.5 – Sequence diagram for FG-200

Table A.6 – Exchanged information in FG-200

Interaction	From > To	Function	Semantics
1-9	FEMS > SG	FEMS sends energy plan	Energy plan describes the consumption, generation, or any other energy services expected to be used during each pre-agreed interval during the planning period. Optionally, requested content of energy plan can be identified in advance between SG and FEMS.
2-1	SG > FEMS	SG responds to plan	Optional confirmation or rejection of plan.

A.3.3.3 FG-300: Smart grid provides stable (longer term) price schedule to facility

A.3.3.3.1 General description

The smart grid provides pricing and related information to the FEMS to support facility development of daily or longer production plans. Selling price for energy sold to the facility and if appropriate purchase price for energy purchased from facility along with coefficients of environmental impact, etc. may be provided. Pricing information is developed by the SG operator using their internal procedures, typically based on generation and delivery costs and efforts to match longer term consumption to supply using price incentives.

The facility planning to be supported by this use case normally aims to organize the resources, including staffing, needed to meet manufacturing targets. Since these plans are normally made for daily or greater time periods, the pricing information needs to remain valid for time frames to support production planning. However, it is recognized that for larger customers, the SG may offer pricing on a much shorter time scale, with such pricing only determined closer to the time of consumption or supply. Thus, two use cases are identified: longer term pricing supported by this use case and shorter term pricing (or price updates) by use case FG-400.

The intent of this use case is the provision of price and related data on the time-scale of the (human) facility energy planner. It could be an annually provided schedule with simple seasonal and time-of-day prices, or it could be a schedule updated monthly or weekly providing more detailed information. The SG issues these schedules, and updated schedules; and the facility energy planner aligns consumption and potential supply with the lowest price, environmental impact or highest revenue time periods as previously discussed in FG-200 (see A.3.3.2).

If only annual or seasonal (“time-of-day”) pricing information is provided, then this use case might be satisfied with manual procedures.

A.3.3.3.2 Detailed description

The numbered items below correspond to the similarly numbered items in the sequence diagram of Figure A.6. For interactions which cross the facility and smart grid interface, their contents are summarized in Table A.7.

- 1) The SG periodically assesses its generation and delivery costs, and the pricing strategies needed to manage, over the longer term, supply and demand; and generates a pricing schedule for the sale and, as appropriate, purchase of energy (or other energy services from the facility). The contents of such schedules and their creation will follow SG internally defined procedures. However, it is expected that the SG will provide sufficient information in such schedules to assist in production planning. For facilities capable of supplying generation, storage, or other energy services to the grid, purchase information may also be included. Where environmental impacts are to be considered, environmental data (e.g., CO₂ emission coefficients) would also be required.

The SG may internally create several schedules, each aimed at customers with specific ranges of capabilities and needs. For customers with a limited ability to adjust consumption, simple fixed seasonal time-of-day energy purchase price schedules may be sufficient. For facilities better able to adjust consumption, more detailed schedules would be appropriate. For facilities able to provide generation and other energy services, the SG may provide pricing for their purchase of these services from the facility. In some cases, the SG may only provide price ranges, with final pricing only able to be established nearer the time of consumption or supply as described in FG-400.

In many situations today, in addition to the price of energy, it is important to recognize the environmental impact of the type of energy being used. Thus, this use case also assumes that the SG may calculate the environmental emission coefficient associated with the energy it provides. Environmental emission coefficients will vary depending upon the energy generation profile within the SG. As available, the provision of this information along with pricing information will allow the facility energy planner to take the environmental emission coefficient of external energy sources into account in their planning.

The SG may require information from FEMS to identify any specific tailoring needed for the schedule. For example, it may require general information about the availability of generation or storage capacity in order to determine the purchase price to be offered for these resources. Such information could be obtained using use case FG-100.

- 2) Optionally, the facility may provide pricing information for energy generation or other services it is prepared to sell to the SG. This may be accompanied with corresponding environmental emission coefficient information. Services which might be offered to the SG include not only generated and supplied electric power, but regulation, storage,

emergency standby backup or other services. The standard selected to meet this use case should be capable of supporting a range of energy services. This optional use case is identified here since it might be satisfied by the same protocol should it be capable of being operated in a symmetric manner.

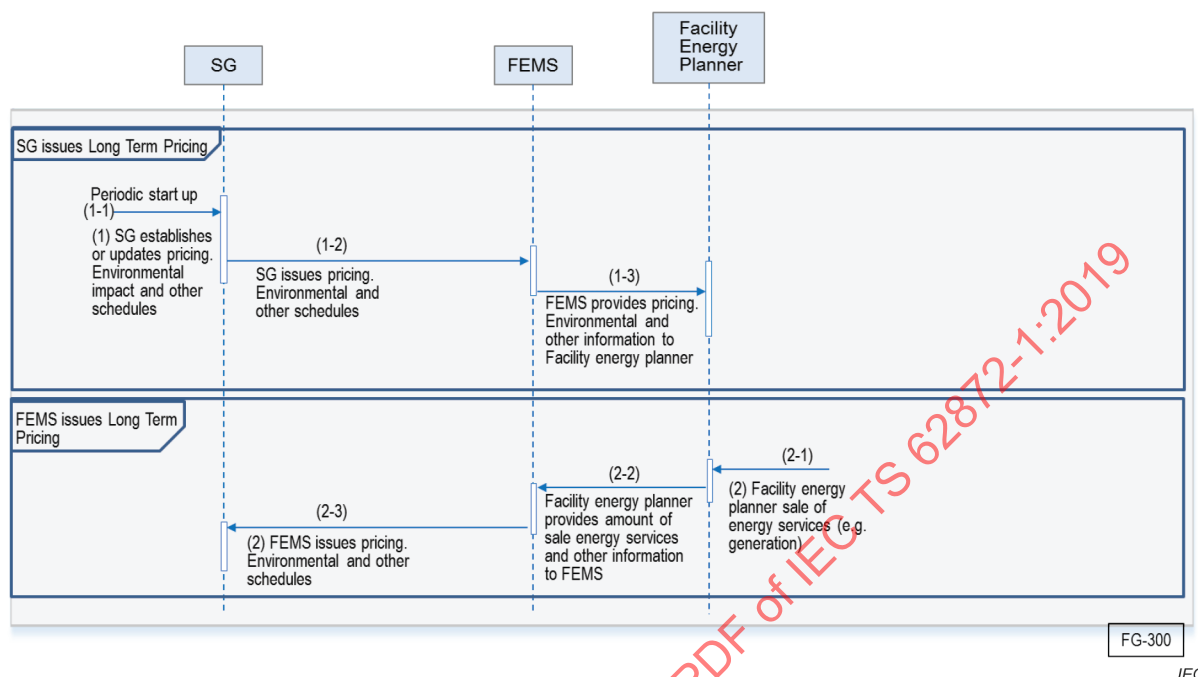


Figure A.6 – Sequence diagram for FG-300

Table A.7 – Exchanged information in FG-300

Interaction	From > To	Function	Semantics
1-2	SG > FEMS	SG issues price, environmental and other schedules	SG provides price schedules covering future period(s) which define the sale price of energy and if appropriate the purchase price of energy and any other energy services offered by the facility. Formats may range from simple manually distributed fixed time-of-day sale prices for energy, to more detailed pricing distributed using this interface for specific intervals of future time.
2-3	FEMS > SG	FEMS issues price, environmental and other schedules	Optional FEMS provides equivalent information for the energy services it offers.

A.3.3.4 FG-400: Smart grid provides dynamic (short term) pricing to facility

A.3.3.4.1 General description

The smart grid provides short term pricing for the facility to adjust its energy use or supply. This information is developed by the SG using internal procedures to maintain balance between generation and supply near the time of use (grid balance). This use case covers the use of pricing as the means to influence energy demand and supply; FG-700, addresses the use of other means. Typically, this information will be used by facilities to manage their current operating consumption and supply of power taking an advantage of hourly variations in the price of energy.

This information would be used by facility control systems to control resources, subject to ensuring that all production safety, performance and product quality requirements are maintained.

A.3.3.4.2 Detailed description

The numbered items below correspond to the similarly numbered items in the sequence diagram of Figure A.7. For interactions which cross the facility and smart grid interface, their contents are summarized in Table A.8.

- 1) The SG implements internal measures to maintain “grid balance”. It determines that one option is to offer pricing changes for a facility to reduce load or provide generation or storage. For example, a facility may decide to accept a request to provide generation if the proposal is acceptable.
- 2) The FEMS receives the offer from the SG and validates that it is within the current capabilities of the facility and that acceptance would be beneficial in meeting financial targets. This validation may be done in conjunction with the facility energy planner and the production planner, including automated entities, within the facility, however it is expected that a prompt decision will need to be made to ensure a prompt reply can be made to the SG.

Acceptance of the offer should also be validated against the ongoing requirements of production, to ensure continued facility safety and the maintenance of production and quality targets. The impact of the requested changes to load and FER should be assessed.

Figure A.7 identifies the production planner as being concerned with this use case. For some facilities, the operations manager may be responsible for the activities of this use case.

The overall ability and desirability of accepting the SG offer is then returned to the SG. If the facility energy planner accepts the offer, the facility energy planner and production planner will facilitate the updating of any facility production plans and any other measures needed to implement the corresponding load reduction or energy service. Optionally the FEMS may initiate FG-500 to report updated energy plan to the SG. If the facility energy planner does not accept the requested change, the SG will need to compensate by taking any other measures needed.

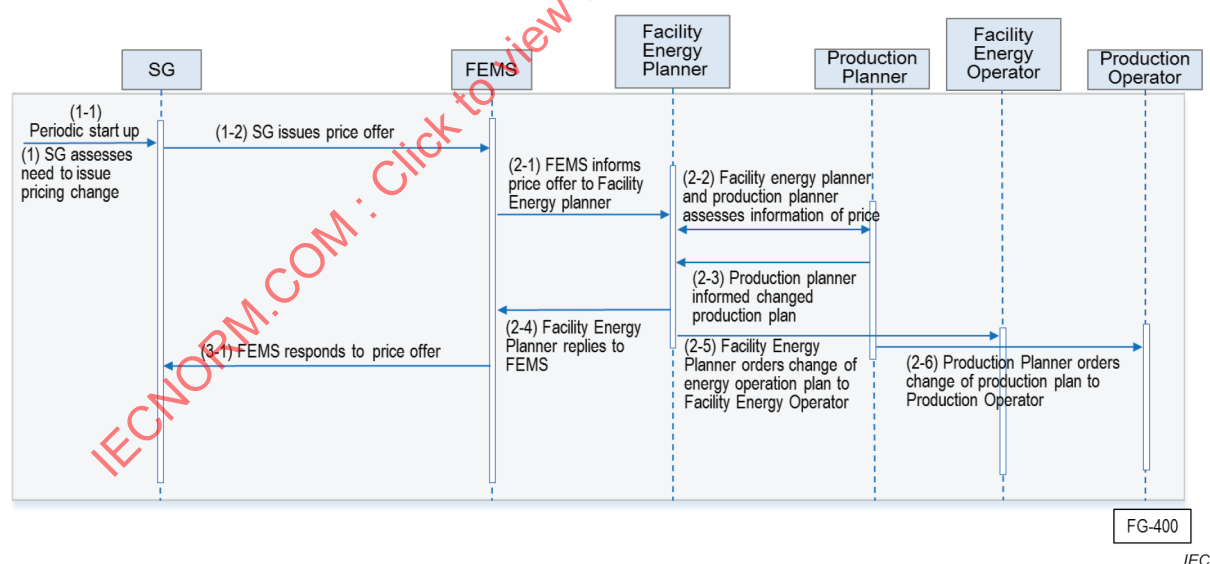


Figure A.7 – Sequence diagram for FG-400

Table A.8 – Exchanged information in FG-400

Interaction	From > To	Function	Semantics
1-2	SG > FEMS	SG issues price offer	SG provides price offer for energy service.
3-1	FEMS > SG	FEMS responds to price offer	FEMS replies to the offer. Contents of response are various.

A.3.3.5 FG-500: Facility informs smart grid about upcoming consumption and supply

A.3.3.5.1 General description

The facility provides information about its upcoming consumption and supply plans to the smart grid. This information is generated nearer to the time of consumption or supply than use case FG-200, and will allow the facility to provide more accurate and timely information. This use case could update previously provided FG-200 information or could be used to provide energy information in cases where the advanced planning supported by FG-200 is not available.

For example, the smart grid may provide discounts if sufficient advance notice of a change in consumption is given, or the facility may need to indicate to the SG upcoming changes to the facility's ability to supply generated energy. Typically, this information may be used by the SG to manage their upcoming estimates of energy use and supply.

A.3.3.5.2 Detailed description

The numbered items below correspond to the similarly numbered items in the sequence diagram of Figure A.8. For interactions which cross the facility and smart grid interface, their contents are summarized in Table A.9.

- 1) The facility determines that a significant change in its expected energy use or supply should be reported to the SG. The requirements for such reporting will depend upon the agreed arrangement between the facility and SG. For example, agreements may be in place requiring the facility to provide minimum notice if it plans to exceed pre-agreed consumption levels or change consumption or supply (ramp-up/ramp-down) at greater than normal rates. In other cases, the availability of unexpectedly available generation capacity could be reported to the SG.

NOTE "Expected energy use or supply" can be that identified previously in use case FG-200 or can simply be the normal energy profile of the Facility.

Events leading to such required changes would typically include unexpected non-availability of input resources for production, equipment breakdown, changes in production targets or weather conditions, or more serious events such as safety issues, earthquakes or floods.

- 2) The SG receives the report from the facility and incorporates the information into their forward SG planning. The SG replies to the update, for example to respond to an offer of generation (if supported).

The FEMS receives any reply provided and assesses whether its contents impact the facility and take action as needed.

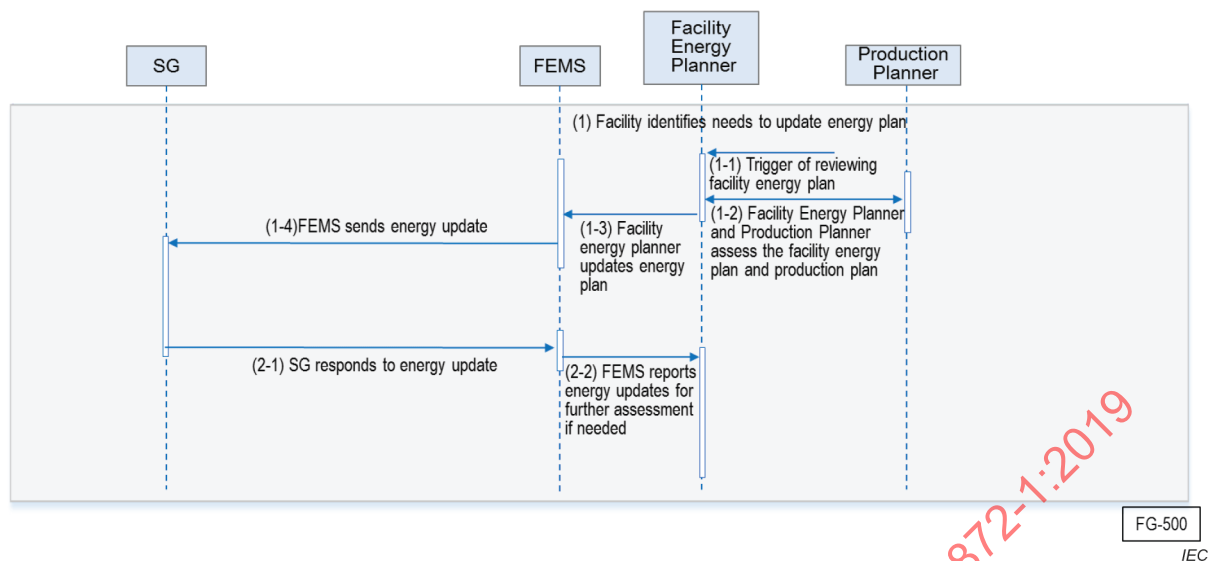


Figure A.8 – Sequence diagram for FG-500

Table A.9 – Exchanged information in FG-500

Interaction	From > To	Function	Semantics
1-4	FEMS > SG	FEMS sends energy update	FEMS provides new or updated energy plan to SG.
2-1	SG > FEMS	SG responds to energy update	SG responds to energy update, e.g., accepting energy generation if it is offered in updated plan.

A.3.3.6 FG-600: Smart grid informs facility of blackout notice

A.3.3.6.1 General description

The smart grid predicts the risk of blackout, brownout, or other abnormal power situation based on weather, equipment availability and status, predicted consumption, and other factors. The SG may develop mitigation plans, such as blackout or brownout schedules, to minimize system wide impacts. Risk and mitigation plans are communicated to the facility which responds by changing energy consumption, power generation or production plans and any other measures necessary to protect the facility, its staff and any ongoing production.

A.3.3.6.2 Detailed description

The numbered items below correspond to the similarly numbered items in the sequence diagram of Figure A.9. For interactions which cross the facility and smart grid interface, their contents are summarized in Table A.10.

- 1) The SG estimates the risk of energy interruption or degraded quality using their internal procedures. For example, such risks may correlate to weather forecasts or the shut-down of significant energy supply or distribution elements. The SG may put into place response plans which involve for example, the implementation of rolling blackouts (scheduled complete power interruptions rotated among delivery areas) or brownouts (reduced voltage delivery).

The SG issues corresponding risk notices providing information about the risk and the implementation of any plans to address the risk, for example a brownout notice.

The content of such notices may vary and will depend upon the information made available by the SG. For most facilities, it will be important to obtain notice in advance of the implementation of a rolling blackout or brownout so that suitable action can be taken to protect the facility and any ongoing production. For larger facilities, notices providing risk estimates of future power interruptions, for example based SG predictions of potential

energy shortages due to weather or other factors, would allow the facility to adjust upcoming production plans to avoid significant consumption, or even provide generation, during high risk periods.

- 2) Upon receipt of the notice, the Facility energy planner updates its facility energy plan as appropriate. The production planner revises production plans to take into account the risks and potential impact. For example, the production may be delayed or suspended at a safe point within the production schedule, if an upcoming power interruption, or high risk of an interruption, has been indicated. The FEMS responds to the SG.

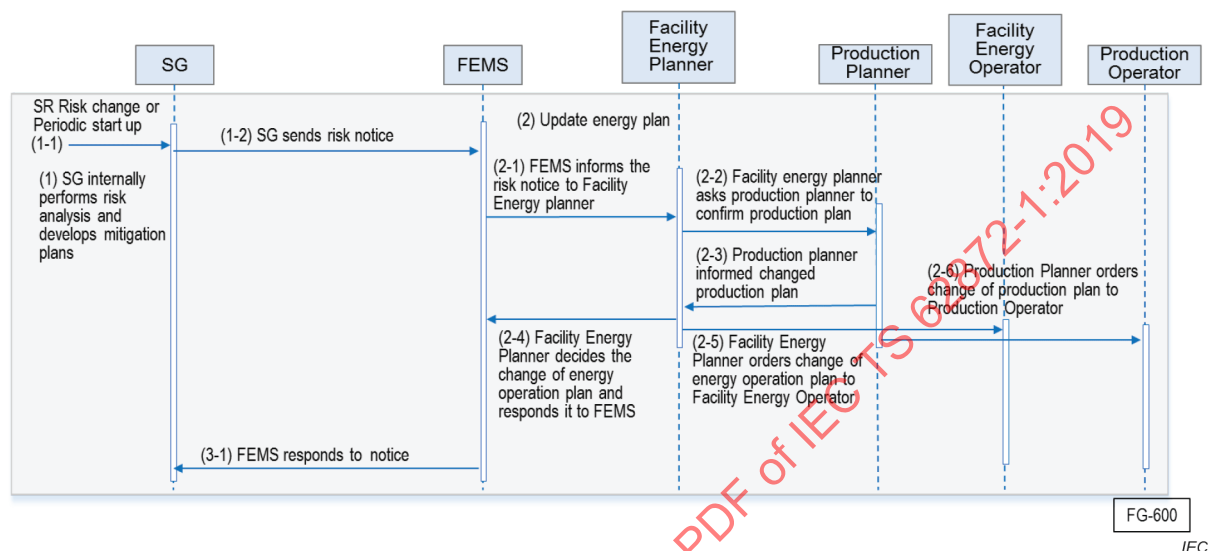


Figure A.9 – Sequence diagram for FG-600

Table A.10 – Exchanged information in FG-600

Interaction	From > To	Function	Semantics
1-2	SG > FEMS	SG sends risk notice	SG provides: a) an indication of the probability of power interruption or power degradation b) specific information about a rolling blackout or brownout along with scheduling information
3-1	FEMS > SG	FEMS responds to notice	FEMS acknowledges the notice. a) with offer to reduce or limit load for risk period b) other response as previously agreed (e.g. request for delay)

A.3.3.7 FG-700: Smart grid requests facility to alter facility's consumption or supply

A.3.3.7.1 General

FG-700 is a series of use cases that the SG requests the facility to change the amount of energy supply to the SG or change consumption of the energy supplied from the SG, according to up-to-date energy balancing plan of the SG. Based on the operational agreements between the facility and the SG, FG-700 is divided into the following two sub-cases:

- The first case (FG-710) is that the SG requests the facility (which consumes energy from the SG) to increase (or decrease) energy consumption, when the SG has excess energy (or energy shortage).
- The second case (FG-720) is that the SG requests the facility (which supplies energy to the SG) to increase (or decrease) energy supply, when the SG has energy shortage (or excess energy).

A.3.3.7.2 FG-710: Smart grid requests facility to increase or decrease consumption

A.3.3.7.2.1 General description

The smart grid regularly monitors energy balance between demand and supply. Once amount of energy in the grid side is observed higher (or lower) than balanced level, for example, due to high photovoltaic power generation caused by sunny weather during holiday season (or low photovoltaic power generation caused by cloudy/rainy weather), the smart grid addresses emergency situation and requests that the facility increases (or decreases) energy consumption as previously agreed. This use case is similar with use case FG-400 except that a specific request is made to make the adjustment rather than using a pricing incentive.

In response, the facility may internally increase (or reduce) loads, alter proposed upcoming consumption plan, decrease (or increase) energy generation. Whether such a request can be rejected by the facility would be based on the agreement previously reached between the parties in respect to the affected energy service.

A.3.3.7.2.2 Detailed description

The numbered items below correspond to the similarly numbered items in the sequence diagram of Figure A.10. For interactions which cross the interface between smart grid and facility, their contents are summarized in Table A.11.

At ahead of time, SG notifies the proposal of DR contract (including incentive) to the facility.

- 1) FEMS reports the proposal to the facility energy planner. Through consulting with the production planner about the DR operation feasibility, facility energy planner decides to agree with the proposal or not. FEMS then responds to SG about the decision of the facility.

During intra-day, SG periodically reviews its energy plan and identifies potential energy excess or shortage.

SG anticipates emergency and invokes a DR event.

- 2) SG requests FEMS to change volume of energy consumption for the requested time period. FEMS reports the request to the facility energy planner, who will then ask the production planner to confirm whether the production plan can be changed for the requested time period. Upon the reply from the production planner, the facility energy planner decides to accept the request or not, and FEMS responds to SG regarding the decision (i.e., acceptance or rejection).

SG dispatches the DR event.

- 3) SG dispatches DR message to FEMS, then the facility energy planner orders the facility energy operator to change the energy operation plan, as well as requests the production planner to change the production plan (i.e., to be executed by the production operator).

SG terminates the DR event and evaluates the demand response performance of facility.

- 4) SG notifies the FEMS of the ending of the DR event and also informs the FEMS of the actual quantity of energy adjustment and the corresponded reward. The FEMS then informs the facility energy planner of the ending of the DR, and the facility energy planner will then inform the production planner of the ending of the altered plan.

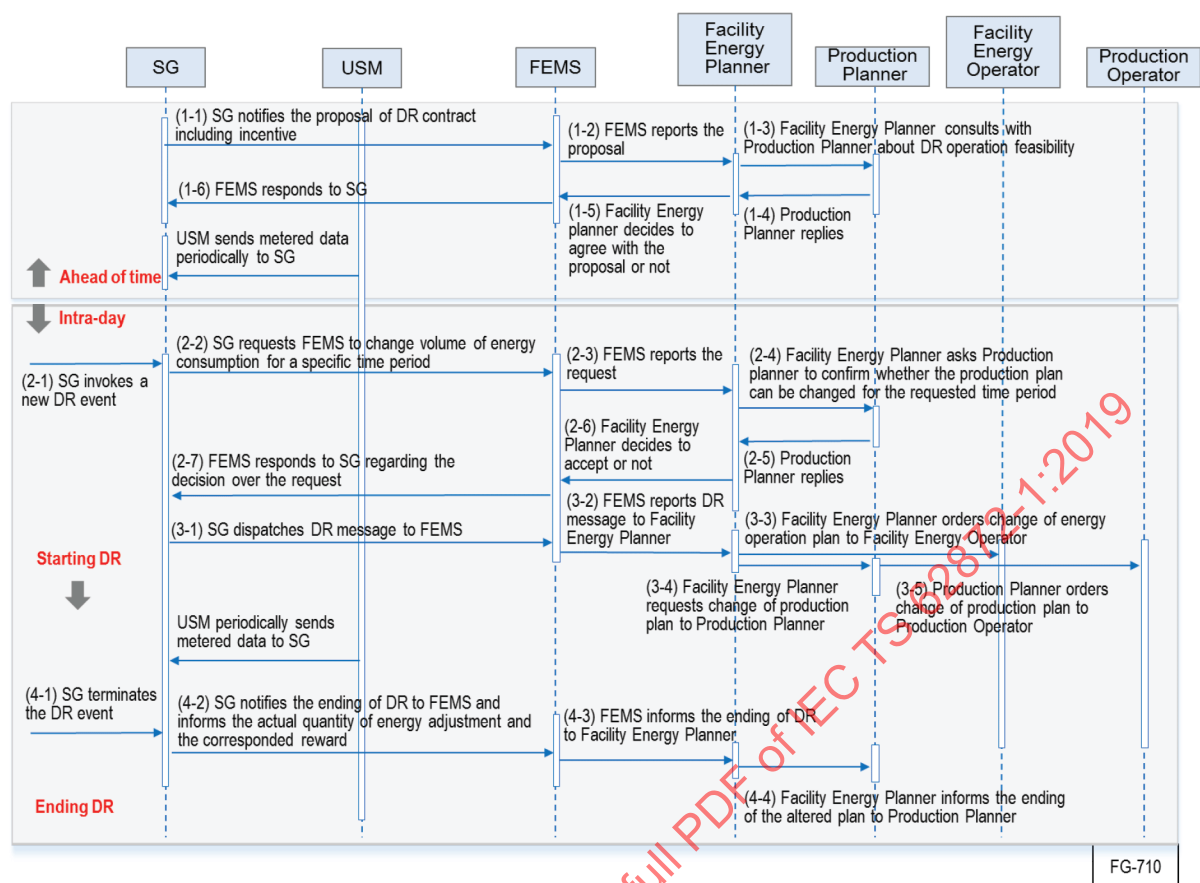


Figure A.10 – Sequence diagram for FG-710

Table A.11 – Exchanged information in FG-710

#	From > To	Function	Semantics
1-1	SG > FEMS	SG notifies DR contract proposal	SG notifies the proposal of DR contract to the facility, including the incentive and other eligible conditions, e.g., minimum power range for adjustment, notification time, sustainable time, and penalty in case of failure of response.
1-6	FEMS > SG	FEMS responds to SG	FEMS responds to SG about the decision of the facility (i.e., agree with the proposal or not).
2-2	SG > FEMS	SG requests facility to change energy consumption	SG requests the facility to change volume of energy consumption for the requested time period.
2-7	FEMS > SG	FEMS responds to SG	FEMS responds to the SG regarding the decision (i.e., acceptance or rejection).
3-1	SG > FEMS	SG dispatches DR message	SG dispatches DR message to the FEMS.
4-2	SG > FEMS	SG notifies the ending of DR to FEMS	SG notifies the ending of DR event to FEMS and also informs FEMS the actual quantity of energy adjustment and the corresponded reward.

A.3.3.7.3 FG-720: Smart grid requests facility to increase or decrease energy supply

A.3.3.7.3.1 General description

The smart grid regularly monitors energy balance between demand and supply. Once amount of energy in the grid side is observed higher (or lower) than balanced level, for example, due to high photovoltaic power generation caused by sunny weather during holiday season (or low photovoltaic power generation caused by cloudy/rainy weather), the smart grid addresses

emergency situations and requests that the facility decreases (or increase) energy supply as previously agreed.

In response, the facility may internally increase (or reduce) loads, alter proposed upcoming supply plan, decrease (or increase) energy generation. Whether such a request can be rejected by the facility would be based on the agreement previously reached between the parties in respect to the affected energy service.

A.3.3.7.3.2 Detailed description

The numbered items below correspond to the similarly numbered items in the sequence diagram of Figure A.11. For interactions which cross the interface between smart grid and facility, their contents are summarized in Table A.12.

At ahead of time, SG notifies the proposal of energy supply contract (including incentive) to the facility.

- 1) FEMS reports the proposal to the facility energy planner. Through consulting with the production planner about the energy supply operation feasibility, facility energy planner decides to agree with the proposal or not. FEMS then responds to SG about the decision of the facility.

During intra-day, SG periodically reviews its energy plan and identifies potential energy excess or shortage.

SG anticipates emergency and invokes an event to manage incoming energy supply.

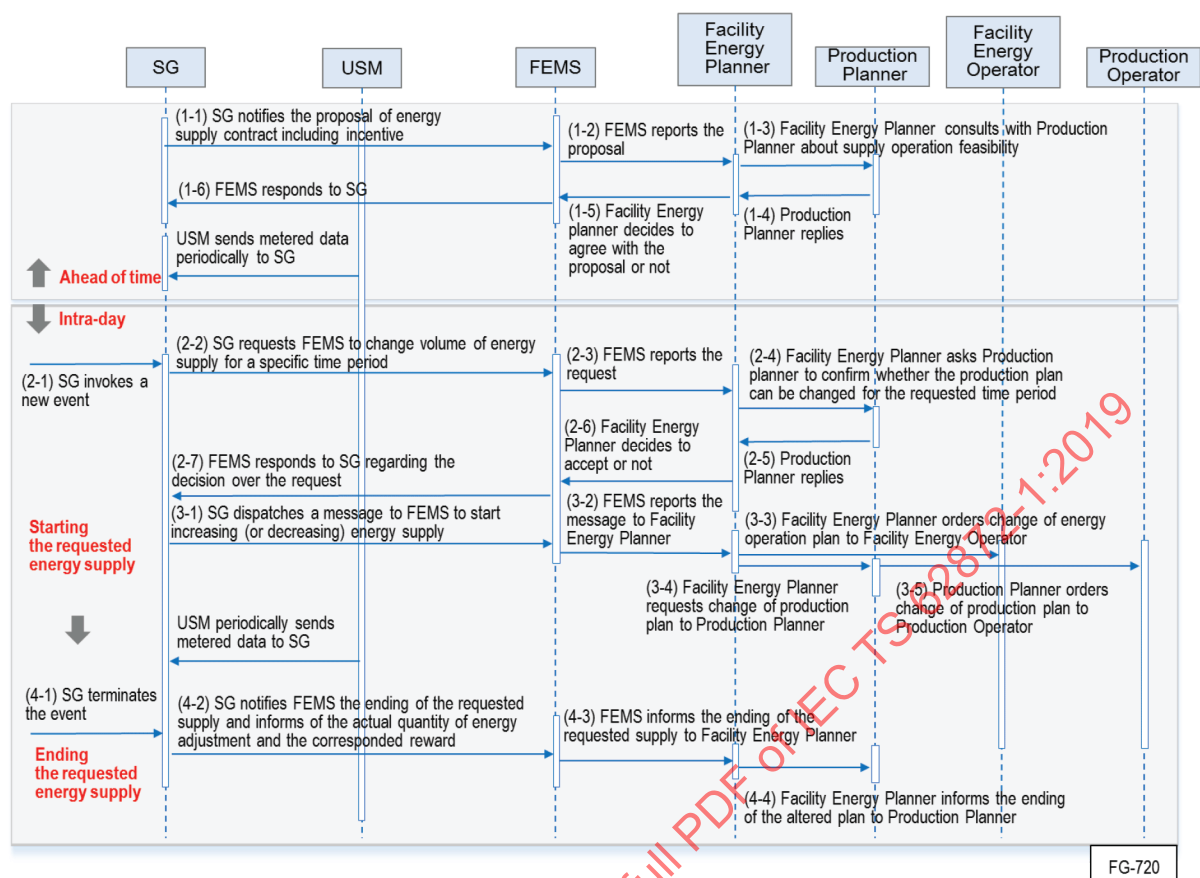
- 2) SG requests FEMS to change volume of energy supply for the requested time period. FEMS reports the request to the facility energy planner, who will then ask the production planner to confirm whether the production plan can be changed for the requested time period. Upon the reply from the production planner, the facility energy planner decides to accept the request or not, and FEMS responds to SG regarding the decision (i.e., acceptance or rejection).

SG dispatches the supply change event.

- 3) SG dispatches supply change message to the FEMS, then the facility energy planner orders the facility energy operator to change the energy operation plan, as well as requests the production planner to change the production plan (i.e., to be executed by the production operator).

SG terminates the event and evaluates the demand response performance of facility.

- 4) SG notifies the FEMS of the ending of the supply change event and also informs the FEMS of the actual quantity of energy adjustment and the corresponded reward. The FEMS then informs the facility energy planner of the ending of the supply change, and the facility energy planner will then inform the production planner of the ending of the altered plan.



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Figure A.11 – Sequence diagram for FG-720

Table A.12 – Exchanged information in FG-720

#	From > To	Function	Semantics
1-1	SG > FEMS	SG notifies energy supply contract proposal	SG notifies the proposal of energy supply contract to the facility, including the incentive and other eligible conditions, e.g., minimum power range for adjustment, notification time, sustainable time, and penalty in case of failure of response.
1-6	FEMS > SG	FEMS responds to SG	FEMS responds to SG about the decision of the facility (i.e., agree with the proposal or not).
2-2	SG > FEMS	SG requests facility to change volume of energy supply	SG requests the facility to change volume of energy supply for the requested time period.
2-7	FEMS > SG	FEMS responds to SG	FEMS responds to the SG regarding the decision (i.e., acceptance or rejection).
3-1	SG > FEMS	SG dispatches supply change message	SG dispatches supply change message to the FEMS.
4-2	SG > FEMS	SG notifies the ending of supply change to FEMS	SG notifies the ending of supply change event to FEMS and also informs FEMS the actual quantity of energy adjustment and the corresponded reward.

A.3.3.8 FG-800: Facility requests smart grid to accept altering facility's consumption or supply

A.3.3.8.1 General

FG-800 is a series of use cases that the facility requests the SG to accept changing the amount of energy supply from the facility to the SG or the amount of energy purchase, according to up-to-date plan of energy management in the facility. Based on the operational

agreements between the facility and the SG, FG-800 is divided into the following two sub-cases:

- The first case (FG-810) is that the facility (which consumes energy from the SG) requests the SG to increase (or decrease) energy supply to the facility, when the facility has energy shortage (or excess energy).
- The second case (FG-820) is that the facility (which supplies energy to the SG) requests the SG to accept facility's increasing (or decreasing) energy supply, when the facility has excess energy (or energy shortage).

A.3.3.8.2 FG-810: Facility requests smart grid to increase or decrease energy supply to facility

A.3.3.8.2.1 General description

The facility monitors and manages its internal energy demand and supply in day to day operation. Once the facility identifies more (or less) amount of energy needs be purchased from the SG for the specific time period, for example, due to unavailability of internal generator (or low production volume which can be covered by internally generated energy), the facility requests that the SG increases (or decreases) energy supply as previously agreed.

In response, the SG may accept the request as long as energy balance can be kept by alternative operation(s) in SG side. Whether such a request can be rejected by the SG would be based on the agreement previously reached between the parties in respect to the affected energy service.

A.3.3.8.2.2 Detailed description

The numbered items below correspond to the similarly numbered items in the sequence diagram of Figure A.12. For interactions which cross the interface between smart grid and facility, their contents are summarized in Table A.13.

- 1) At ahead of time, Facility Energy Planner discuss energy generation, storage and usage plan with Production Planner considering demand and resource allocation variations, then decides and notifies SG, through FEMS, the proposal of energy purchase contract (including volume change option). SG responds to FEMS about acceptance.
- 2) During intra-day, when a specific situation is observed that energy operation plan and/or production plan need to be changed with different volume of energy from SG, Facility Energy Planner sends a message to SG through FEMS requesting to increase (or decrease) energy supply to facility. SG responds to FEMS with confirmation.
- 3) The confirmed energy operation plan and/or production plan is started in facility side.
- 4) The Facility Energy Planner and/or the Production planner announce the end of the plan. After internal confirmation by the Facility Energy Planner, the FEMS notifies the SG of the end of the requested energy supply to the facility. The SG confirms that to the facility and informs the facility of the actual quantity of energy adjustment and the corresponded compensation.

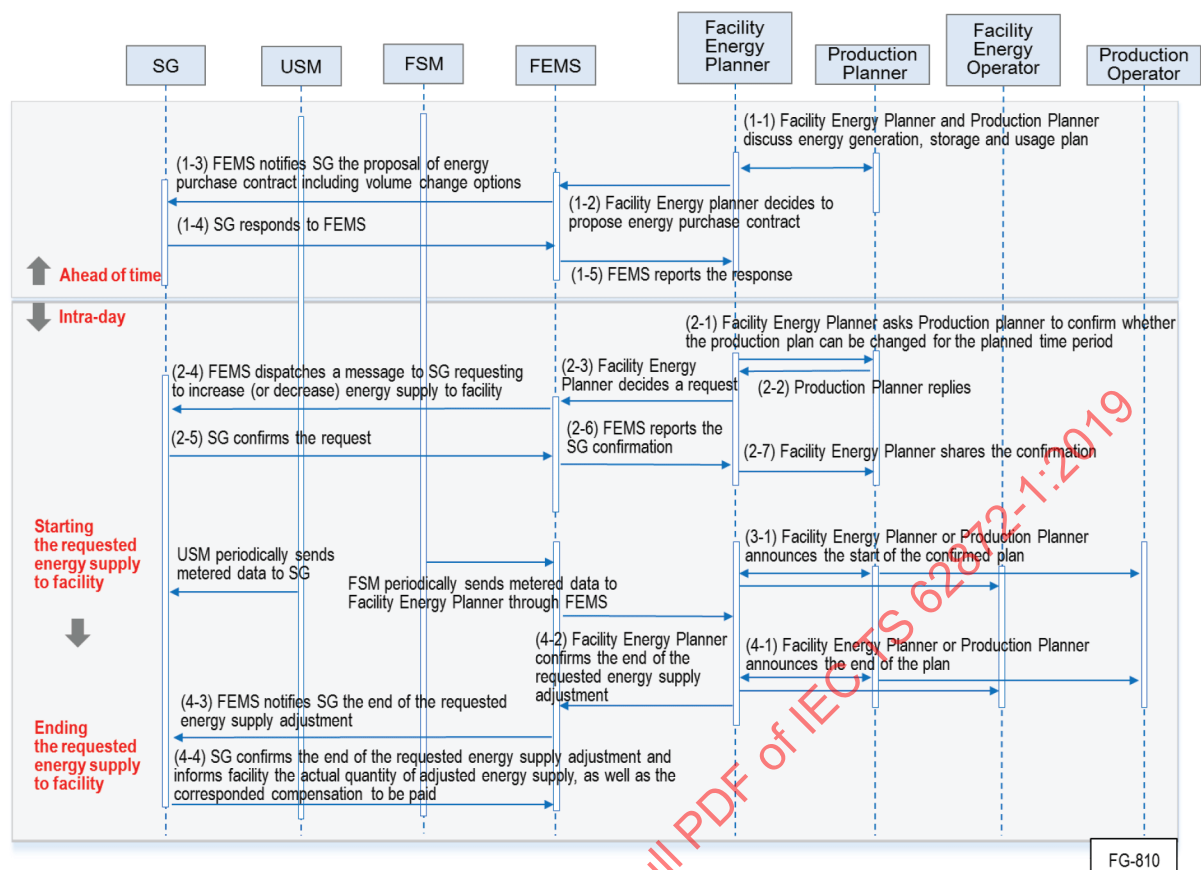


Figure A.12 – Sequence diagram for FG-810

Table A.13 – Exchanged information in FG-810

#	From > To	Function	Semantics
1-3	FEMS > SG	FEMS notifies SG the proposal of energy purchase contract including volume change options.	FEMS notifies SG the proposal of energy purchase contract, including volume change options, e.g. some possible cases when purchasing energy volume needs to be increased or decreased to solve internal problem for certain time period.
1-4	SG > FEMS	SG responds to FEMS	SG responds to FEMS about the agreement with the proposal.
2-4	FEMS > SG	FEMS dispatches a message to SG requesting to increase (or decrease) energy supply to facility	FEMS requests SG to increase (or decrease) specific volume of energy supply to facility for the demanding period with starting time and ending time.
2-5	SG > FEMS	SG confirms the request	SG confirms the message and replies to FEMS with its possible operation.
4-3	FEMS > SG	FEMS notifies SG the end of the requested energy supply adjustment	FEMS notifies SG the end of the requested energy supply to facility and way to resume back to an agreed operation defined in purchase contract.
4-4	SG > FEMS	SG confirms the end of the requested energy supply adjustment and informs facility the actual quantity of adjusted energy supply, as well as the corresponded compensation to be paid	SG confirms the end of the requested energy supply operation and informs the actual volume of energy supply for the period and the corresponded compensation with accounting.

A.3.3.8.3 FG-820: Facility requests smart grid to accept facility's increasing or decreasing energy supply

A.3.3.8.3.1 General description

The facility monitors and manages its internal energy demand and supply in day to day operation. Once the facility identifies more (or less) amount of energy can be supplied to the SG for the specific time period, because, for example, additional surplus energy is suitable for selling (or more energy is needed for internal production instead of selling), the facility requests the SG to accept that facility increases (or decreases) energy supply as previously agreed.

In response, the SG may accept the request as long as energy balance can be kept by alternative operation(s) in SG side. Whether such a request can be rejected by the SG would be based on the agreement previously reached between the parties in respect to the affected energy service.

A.3.3.8.3.2 Detailed description

The numbered items below correspond to the similarly numbered items in the sequence diagram of Figure A.13. For interactions which cross the interface between smart grid and facility, their contents are summarized in Table A.14.

- 1) At ahead of time, Facility Energy Planner discuss energy generation, storage and usage plan with Production Planner considering demand and resource allocation variations, then decides and notifies SG, through FEMS, the proposal of energy supply contract (including volume change option). The SG responds to FEMS about acceptance.
- 2) During intra-day, when a specific situation is observed that energy operation plan and/or production plan need to be changed and that supply volume of energy to SG also needs to be changed, Facility Energy Planner sends a message to SG through FEMS requesting to accept facility's increasing (or decreasing) energy supply to the SG. The SG responds to FEMS with confirmation.
- 3) The confirmed energy operation plan and/or production plan is started in facility side.
- 4) The Facility Energy Planner and/or Production planner announce the end of the plan. After internal confirmation by Facility Energy Planner, the FEMS notifies the SG of the end of accepted energy supply to SG. SG confirms that to the facility and informs the facility of the actual quantity of supplied volume and the corresponded compensation.

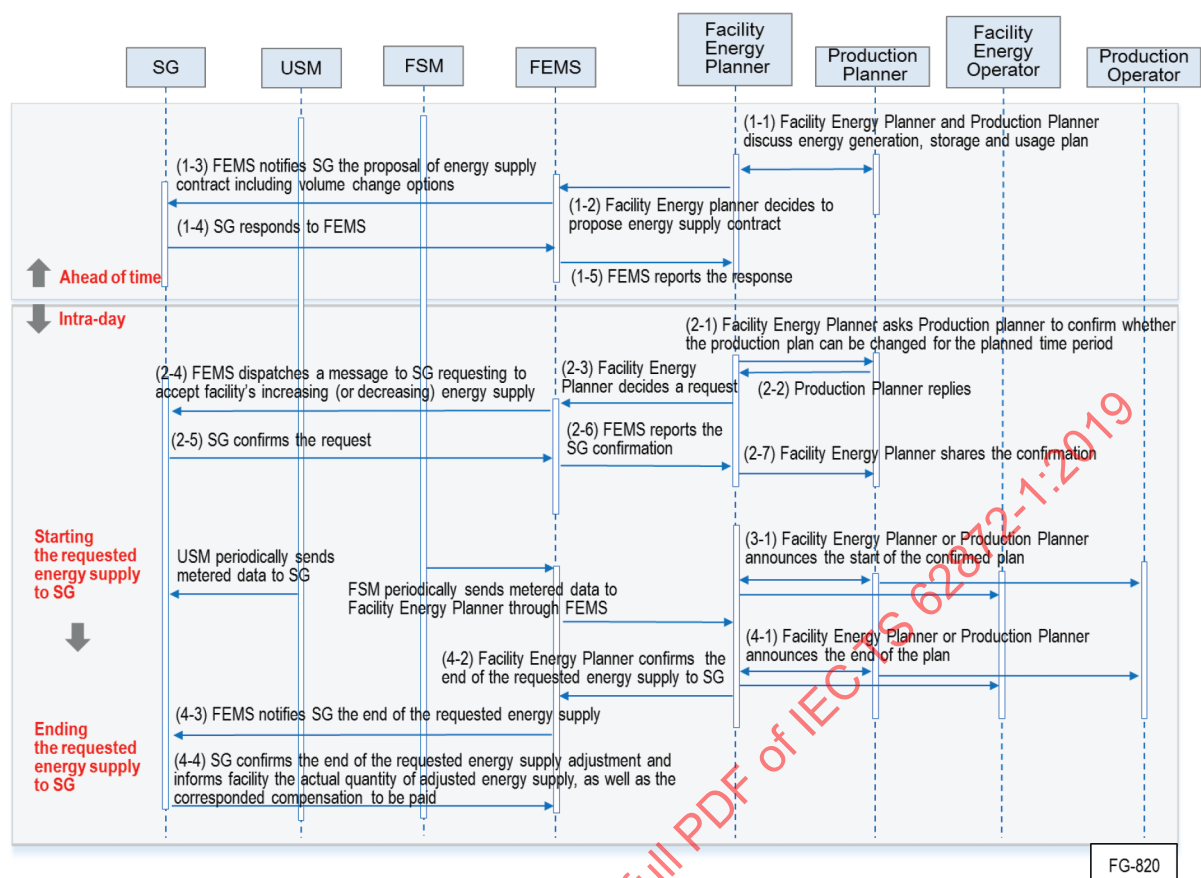


Figure A.13 – Sequence diagram for FG-820

Table A.14 – Exchanged information in FG-820

#	From > To	Function	Semantics
1-3	FEMS > SG	FEMS notifies SG the proposal of energy supply contract including volume change options	FEMS notifies SG the proposal of energy supply contract, including volume change options, e.g. some possible cases when supplying energy volume needs to be increased or decreased to solve internal problem for certain time period.
1-4	SG > FEMS	SG responds to FEMS	SG responds to FEMS about the agreement with the proposal.
2-4	FEMS > SG	FEMS dispatches a message to SG requesting to accept facility's increasing (or decreasing) energy supply to SG	FEMS requests SG to accept that facility increases (or decreases) specific volume of energy supply to SG for the demanding period with starting time and ending time.
2-5	SG > FEMS	SG confirms the request	SG confirms the message and replies to FEMS with its possible operation.
4-3	FEMS > SG	FEMS notifies SG the end of the requested energy supply	FEMS notifies SG the end of the requested energy supply to SG and way to resume back to an agreed operation defined in supply contract.
4-4	SG > FEMS	SG confirms the end of the requested energy supply adjustment and informs facility the actual quantity of adjusted energy supply, as well as the corresponded compensation to be paid	SG confirms the end of the requested energy supply operation and informs the actual quantity of supplied volume for the period and the corresponded compensation with accounting.

Annex B

(normative)

Use cases of incentive-based DR programs

B.1 General

Incentive-based demand response (IBDR) programs are established by smart grid operator which might be a utility, a retail electricity supplier or a regional grid operator, to elicit demand reductions from customers at critical times called program “events”. These programs give customers load-reduction incentives that are separate from, or additional to their retail electricity rate which may be fixed or time-varying. The load reductions are needed and requested to either solve reliability problems, or achieve specific operational goals, e.g., localized load reductions to relieve transmission congestion. Most demand response programs specify a method for establishing customers’ baseline energy consumption level, so observers (utilities, load serving entities, or a regional grid operator) can measure and verify the magnitude of their load response, the procedure of regulating a customer’s baseline is out of scope of this document. Some programs penalize customers that enrol but fail to respond or fulfil their contractual commitments when events are declared.

Industrial facilities are the most promising “electricity customers” to provide demand response resources in the electric system planning process. According to different timescales of commitment, there are broadly six types of incentive-based programs. As shown in Figure B.1, direct load control can be utilized by the smart grid to handle the grid emergency less than 15 minutes before power delivery or load reduction delivery timing (i.e., real-time). Interruptible/curtailable load and emergency DR programs can be called by the smart grid to give remedy resolution to grid reliability issues during intra-day. At day-ahead time, the smart grid can guide facilities to collaborate to provide more economic scheduling, these programs include demand bidding and ancillary service. For the former, smart grid allows facilities to submit energy bids which then will be cleared using a specific economic dispatch method; for the latter, the potential load reduction provided by a qualified facility can also act as an ancillary service resource to provide operating reserve or regulation service when needed, and the negotiation between smart grid and facilities can also be done in a longer term. Capacity market programs are typically offered to facilities that can commit to providing pre-specified load reductions when system contingencies arise, those pre-defined load reductions therefore increase system capacity for the smart grid. Like conventional generation resources, the actual delivery of all the committed load reductions occurs in real time.

Note that the above mentioned six IBDRs are real examples, which have already been implemented and operated in the market [5, 6].

Next, six use cases are presented to give a brief guidance for deploying incentive-based DR programs between the smart grid and industrial facilities, and will also be used to evaluate candidate solutions (existing and under development standards capable of supporting the corresponding use cases).

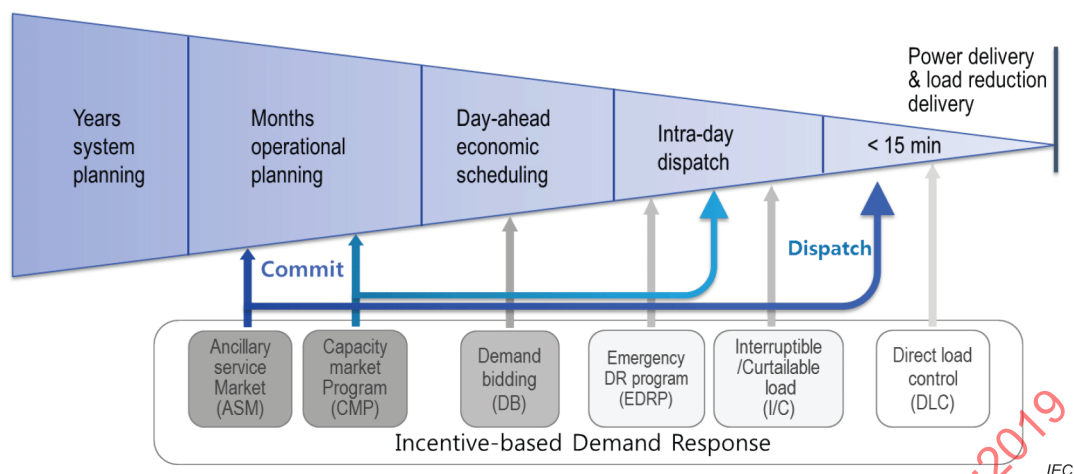


Figure B.1 – Role of incentive-based demand response in electric system planning and operations

B.2 Use cases of incentive-based DR (IBDR) programs

B.2.1 Use case analysis

Clause B.2 derives specific incentive-based demand response use cases based on the high level facility user stories (FUSs) in Table A.1 and utility user stores (UUSs) in Table A.2. These use cases will be used to evaluate candidate solutions (existing and under development standards capable of supporting the corresponding use cases).

Each of use case is summarized below.

- 1) IBDR-1: Smart grid directly controls the load of facility.

The smart grid remotely shuts down the load of a facility to address system reliability contingencies, in exchange of paying the facility participation payment in advance.

- 2) IBDR-2: Smart grid requests facility to curtail load during system contingencies.

The smart grid issues “incentive” to a facility for agreeing to reduce load during system contingencies, a facility will be penalized if it does not reduce load.

- 3) IBDR-3: Smart grid informs facility to provide load reductions during a reliability-triggered event.

The smart grid provides incentive payment to a facility for measured load reduction during a reliability-triggered event, no penalty is imposed if the facility does not respond.

- 4) IBDR-4: Smart grid informs facility to offer bids to the energy market.

The smart grid allows a facility to bid load reduction into the energy market, a facility with accepted bid shall reduce load as contracted, otherwise it faces a penalty.

- 5) IBDR-5: Smart grid informs facility to provide predefined load reduction as the system capacity.

The smart grid provides a facility with guaranteed payment for committing to provide predefined load reduction as the system capacity, a facility will face a penalty if it does not reduce load during a DR event.

- 6) IBDR-6: Smart grid allows facility to bid load reduction into the ancillary service market.

The smart grid allows a qualified facility to bid load reduction into the ancillary service market as operating reserves, a facility with accepted bid shall curtail load when called by the smart grid operator, otherwise it faces a penalty.

The dependency between user stories and use cases is shown in Table B.1.

Table B.1 – Dependency between user stories and use cases

User story	IBDR-1 (DLC)	IBDR-2 (I/C)	IBDR-3 (EDRP)	IBDR-4 (DB)	IBDR-5 (CMP)	IBDR-6 (ASM)
FUS1						
FUS2						
FUS3						
FUS4	x			x	x	x
FUS5						
FUS6						
FUS7		x	x	x	x	x
FUS8						
FUS9						
FUS10		x	x	x	x	x
FUS11						
FUS12		x	x	x	x	x
UUS1	x	x	x	x	x	x
UUS2	x	x	x	x	x	x
UUS3	x	x	x	x	x	x

B.2.2 Use case description

B.2.2.1 IBDR-1: Direct load control (DLC)

B.2.2.1.1 General description

Direct load control is a program in which the smart grid operator remotely shuts down or cycles a facility's electrical load on short notice to address system or local reliability contingencies. Facilities often receive a participation payment in advance, e.g., in the form of an electricity bill credit, in exchange the smart grid operator installs a switch at the facility and the loads connected with the switch will be directly dispatched later on.

B.2.2.1.2 Detailed description

The numbered steps in the following description correspond to the similarly numbered items in the interaction sequence diagram of Figure B.2. The information flows that cross the interface between the SG and facility are summarized in Table B.2.

At ahead time, SG initializes the negotiation with a facility.

- 1) SG issues "incentive" and eligible conditions to this facility in advance. FEMS reports to facility energy planner, who will consult production planner to assess the feasibility of load reduction under the direct load control of SG. Then facility energy planner makes final decision regarding the acceptance or rejection of SG offer, meanwhile a response is sent from FEMS to SG indicating the decision. In case of acceptance, SG will issue incentive payments for the enrollment and may sign a contract with the facility to confirm the transaction.

NOTE 1 SG can install a switch or switches at the facility for preparation of future request of direct load control. In this way, the load connected with the switch will be directly dispatched by the SG during a DR event.

During intra-day, SG periodically reviews its energy plan and identifies potential energy shortfalls, or system reliability contingencies.

In case of urgent situation, SG dispatches a DR event.

- 2) SG informs the FEMS about the upcoming direct load control on short notice, e.g., 5 minutes ahead of time. After the notification time elapses, SG directly controls the load to reduce the energy consumption below predefined threshold.

SG terminates the DR event and evaluates the demand response performance of facility.

- 3) SG notifies the ending of DR event to FEMS. FEMS then informs the ending of DR to facility energy planner and production planner, who may inform production operator to recover the load.

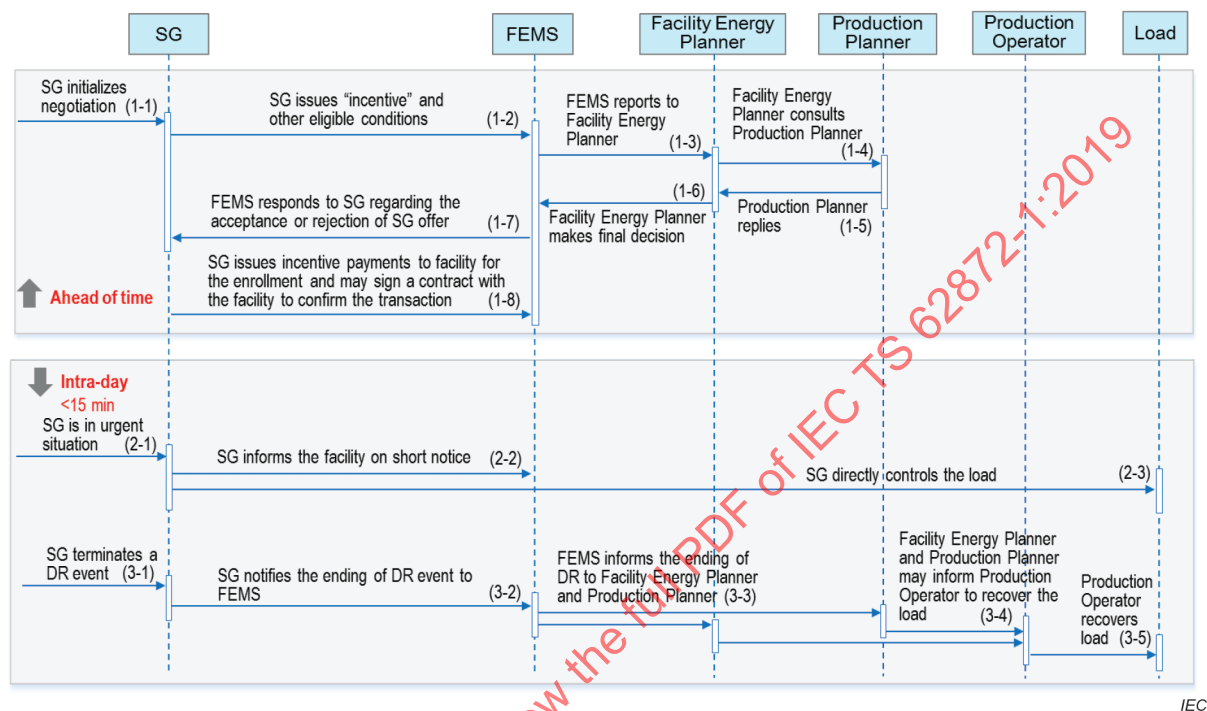


Figure B.2 – Sequence diagram for IBDR-1 (DLC)

Table B.2 – Exchanged information in IBDR-1 (DLC)

#	From > To	Function	Semantics
1-2	SG > FEMS	SG notifies incentive	SG notifies incentive and other eligible conditions to the facility, including the payment, minimum load reduction, frequency of activations, etc.
1-7	FEMS > SG	FEMS responds to SG	FEMS responds to SG regarding the acceptance or rejection of the offer.
1-8	SG > FEMS	SG issues incentive payments	SG issues incentive payments to facility for enrolling in the DLC program and may sign a contract with the facility to confirm the transaction.
2-2	SG > FEMS	SG informs DR signal	SG informs the facility about the upcoming direct load control on short notice.
2-3	SG > Load	SG directly controls the load	SG directly controls the load to reduce the energy consumption below predefined threshold.
3-2	SG > FEMS	SG notifies the ending of DR to FEMS	SG notifies the ending of DR event to FEMS.

B.2.2.2 IBDR-2: Interruptible Curtailable (I/C) Load

B.2.2.2.1 General description

This use case is applicable for the smart grid to handle system contingencies during intra-day. The smart grid operator provides facilities with "incentive" (e.g., electricity rate discount) a

short period ahead of the power deliver time, to encourage facilities to make load curtailment options. Later during a DR event, the smart grid will call those facilities to curtail loads according to their load reduction options, facilities that do not respond to the “call” will face penalties.

B.2.2.2.2 Detailed description

The numbered steps in the following description correspond to the similarly numbered items in the interaction sequence diagram of Figure B.3. The information flows that cross the interface between the SG and facility are summarized in Table B.3.

During intra-day, the SG periodically reviews its energy plan, and identifies potential energy shortfalls or anticipates system contingencies.

SG then issues “incentive” and other eligible conditions to the facility.

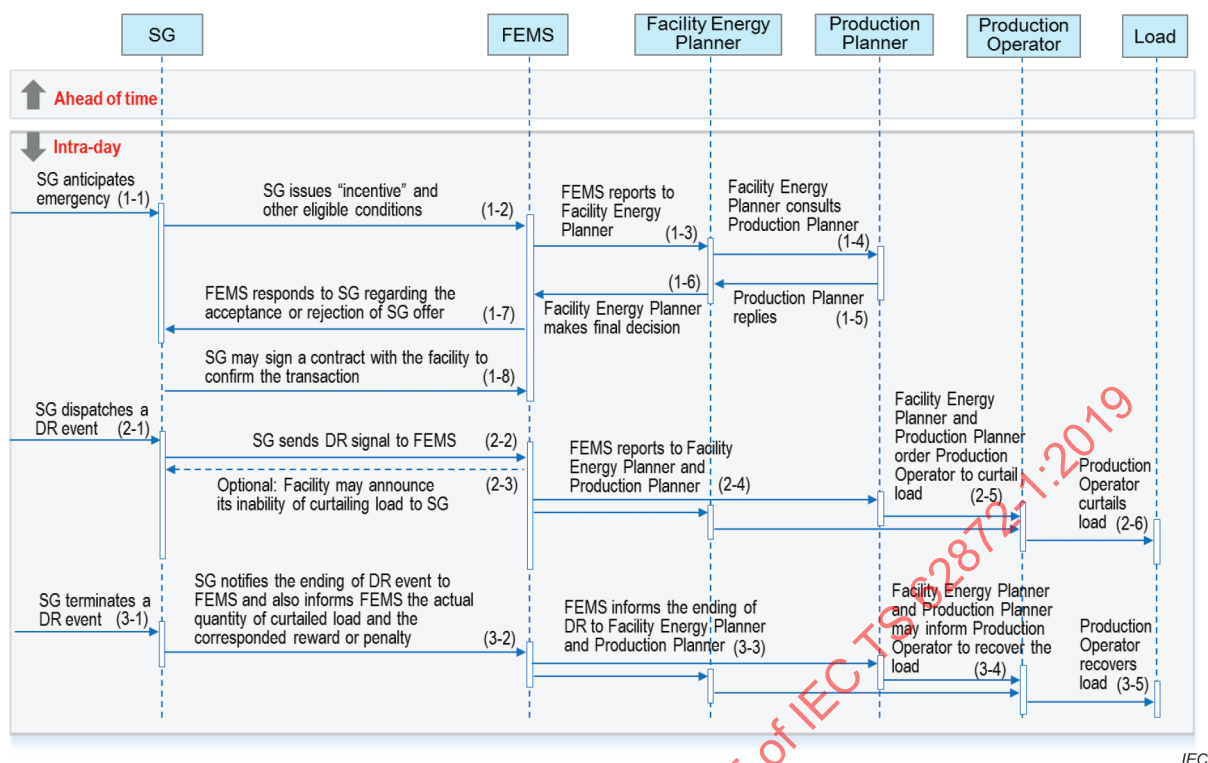
- 1) FEMS reports to facility energy planner, who will consult production planner to assess the feasibility of load reduction options. Then facility energy planner makes final decision regarding the acceptance or rejection of SG offer, meanwhile a response is sent from FEMS to SG indicating the decision as well as the related load reduction options in case of acceptance. In addition, SG may sign a contract with the facility to confirm the transaction.

SG dispatches a DR event.

- 2) SG sends DR signal to the facility to curtail load according to the agreed load reduction options. Optionally, facility may announce its inability of curtailing load to SG. Otherwise, FEMS reports the DR signal to facility energy planner and production planner, who will then order production operator to curtail load after the notification time elapses. Meanwhile, the adjustments to any production plans (see use case FG-200) are also made by production planner accordingly.

SG terminates the DR event and evaluates the demand response performance of facility.

- 3) SG notifies the ending of DR event to FEMS, and also informs FEMS the actual quantity of curtailed load as well as the corresponded reward or penalty in case of failure of response. FEMS then informs the ending of DR to facility energy planner and production planner, who may inform production operator to recover the load.



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Figure B.3 – Sequence diagram for IBDR-2 (I/C)

Table B.3 – Exchanged information in IBDR-2 (I/C)

#	From > To	Function	Semantics
1-2	SG > FEMS	SG issues incentive and other eligible conditions	SG issues incentive (e.g., \$/kW or \$/MW) and eligible conditions to the facility: minimum bid size, frequency of activations, notification time, sustainable time, capped number of times or hours per year, penalty in case of failure of response.
1-7	FEMS > SG	FEMS responds to SG	FEMS responds to SG regarding the acceptance or rejection of the offer as well as the related load reduction options in case of acceptance.
1-8	SG > FEMS	SG signs contract with facility	SG may sign a contract with the facility to confirm the transaction, such a contract may specify the incentive size, quantity of curtailed load, duration, penalty size.
2-2	SG > FEMS	SG sends DR signal	SG sends DR signal to the facility to curtail load according to the agreed load reduction options.
2-3	FEMS > SG	FEMS responds to SG	Facility may announce its inability of curtailing load to SG for this DR event (optional).
3-2	SG > FEMS	SG notifies the ending of DR to FEMS	SG notifies the ending of DR event to FEMS and also informs FEMS the actual quantity of curtailed load based on customer load baseline, and the corresponded reward or penalty in case of failure of response.

B.2.2.3 IBDR-3: Emergency Demand Response Program (EDRP)

B.2.2.3.1 General description

This use case can be invoked by the smart grid during intra-day, to provide incentive payments to customers for measured load reductions during reliability-triggered events; the smart grid will pay for facilities based on the actual load curtailments and there is no penalty if a facility does not curtail any load amount.

B.2.2.3.2 Detailed description

The numbered steps in the following description correspond to the similarly numbered items in the interaction sequence diagram of Figure B.4. The information flows that cross the interface between the SG and facility are summarized in Table B.4.

During intra-day, the SG periodically reviews its energy plan, and dispatches a DR event when SG identifies potential energy shortfalls or anticipates system contingencies.

SG issues “incentive” and other eligible conditions to the facility.

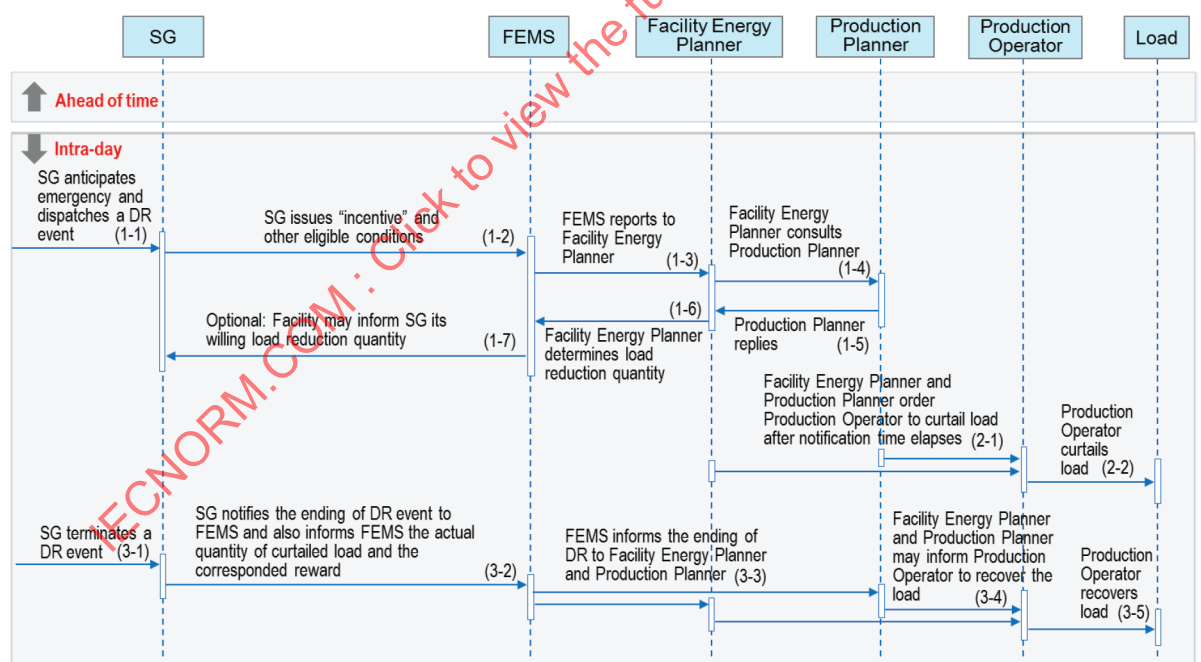
- 1) FEMS reports to facility energy planner, who will consult production planner to assess the feasibility of load reduction options. Then facility energy planner determines the load reduction quantity. Optionally, facility may inform SG its willing load reduction quantity upon the provided incentive.

After the notification time elapses, facility starts to execute load reduction.

- 2) Facility energy planner and production planner order production operator to curtail load after the notification time elapses. Meanwhile, the adjustments to any production plans (see use case FG-200) are also made by production planner accordingly.

SG terminates the DR event and evaluates the demand response performance of facility.

- 3) SG notifies the ending of DR event to FEMS, and also informs FEMS the actual quantity of load reduction as well as the corresponded reward. FEMS then informs the ending of DR to facility energy planner and production planner, who may inform production operator to recover the load.



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Figure B.4 – Sequence diagram for IBDR-3 (EDRP)

Table B.4 – Exchanged information in IBDR-3 (EDRP)

#	From > To	Function	Semantics
1-2	SG > FEMS	SG issues incentive and other eligible conditions	SG issues incentive (e.g., \$/kW or \$/MW) and eligible conditions to the facility: minimum load reduction, notification time, sustainable time.
1-7	FEMS > SG	FEMS responds to SG	FEMS may optionally inform SG its willing load reduction upon the provided incentive.
3-2	SG > FEMS	SG notifies the ending of DR to FEMS	SG notifies the ending of DR event to FEMS and also informs FEMS the actual quantity of curtailed load based on customer load baseline, and the corresponded reward.

B.2.2.4 IBDR-4: Demand Bidding (DB)

B.2.2.4.1 General description

This use case can be deployed by the smart grid to allow a facility to bid load reductions into the wholesale electricity market at a price at which it is willing to curtail load, or to encourage a facility to identify how much load it is willing to curtail at a utility-posted price. For the latter case, a utility-posted price is a resemblance with the “incentive” in B.2.2.3. The bidding process should be done ahead of time, typically one day ahead. When system contingencies occur during intra-day, a facility whose load reduction bid is accepted shall either curtail load as contracted or face a penalty if called by the smart grid.

B.2.2.4.2 Detailed description

The numbered steps in the following description correspond to the similarly numbered items in the interaction sequence diagram of Figure B.5. The information flows that cross the interface between the SG and facility are summarized in Table B.5.

At day-ahead time, SG calls for demand bidding program and notifies a facility the eligible conditions for submitting load reduction bids.

- 1) FEMS reports to facility energy planner, who will consult production planner to assess the feasibility of load reduction options. Then facility energy planner calculates possible load reduction bids. As a response, FEMS submits its bids to SG in terms of a pair or pairs, i.e., (bid size, bid price).

SG clears the energy market using some economic dispatch method and determines the winning bids.

- 2) SG notifies the accepted bid and signs a contract with facility specifying details related with the transaction. Optionally, FEMS may inform SG that this facility is acknowledged as a candidate DR resource.

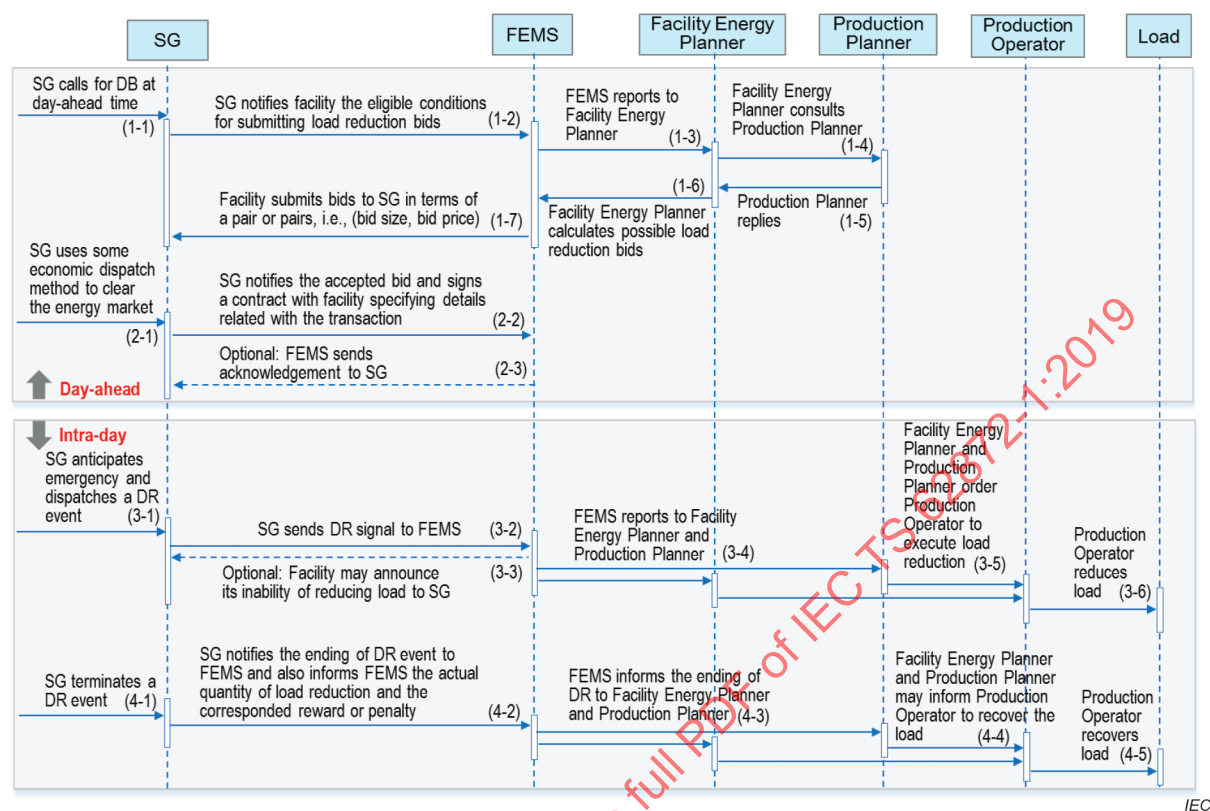
During intra-day, the SG periodically reviews its energy plan, and dispatches a DR event in case SG identifies potential energy shortfalls or anticipates system contingencies.

- 3) SG sends DR signal to the facility to reduce load according to the accepted load reduction bid. Optionally, facility may announce its inability of reducing load to SG. Otherwise, FEMS reports the DR signal to facility energy planner and production planner, who will then order production operator to execute the load reduction after the notification time elapses. Meanwhile, the adjustments to any production plans (see use case FG-200) are also made by production planner accordingly.

SG terminates the DR event and evaluates the demand response performance of facility.

- 4) SG notifies FEMS of the ending of the DR event, and also informs FEMS of the actual quantity of load reduction as well as of the corresponding reward or penalty in case of failure of response. FEMS then informs the facility energy planner and the production

planner of the ending of the DR, who may inform the production operator to recover the load.



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Figure B.5 – Sequence diagram for IBDR-4 (DB)

Table B.5 – Exchanged information in IBDR-4 (DB)

#	From > To	Function	Semantics
1-2	SG > FEMS	SG calls for bids	SG notifies facility to submit load reduction bids and also notifies the eligible conditions: minimum bid size, notification time, sustainable time, penalty in case of failure of response.
1-7	FEMS > SG	FEMS responds to SG	FEMS submits its bids to SG in terms of a pair or pairs, i.e., (bid size, bid price).
2-2	SG > FEMS	SG notifies the accepted bid and signs contract with facility	SG clears the energy market using economic dispatch method and determines the winning bid; meanwhile, a contract can be made between two sides specifying the accepted bid size, interval of bid, penalty size.
2-3	FEMS > SG	Facility sends acknowledgement to SG	Optionally FEMS may send acknowledgement to SG indicating its confirmation of being a candidate DR resource
3-2	SG > FEMS	SG sends DR signal	SG sends DR signal to the facility to execute load reduction according to the accepted load reduction bid.
3-3	FEMS > SG	FEMS responds to SG	Facility may announce its inability of reducing load to SG for this DR event (optional).
4-2	SG > FEMS	SG notifies the ending of DR to FEMS	SG notifies the ending of DR event to FEMS, and also informs FEMS the actual quantity of curtailed load based on customer load baseline, as well as the corresponded reward or penalty in case of failure of response.

B.2.2.5 IBDR-5: Capacity Market Program (CMP)

B.2.2.5.1 General description

This use case can be utilized by the smart grid to encourage facilities to provide predefined load reductions, which then can replace conventional generation and increase the system capacity. Participated facilities are obliged to provide a minimum load curtailment, for which the smart grid provides guaranteed reservation payments even if these facilities are not called during a DR event. A facility typically receives intra-day notice of DR events from the smart grid, and the smart grid pays additional energy payments to the facility for actual load reductions during a DR event. A facility will face significant penalties if it does not obligate its load curtailment when called by the smart grid during a DR event.

B.2.2.5.2 Detailed description

The numbered steps in the following description correspond to the similarly numbered items in the interaction sequence diagram of Figure B.6. The information flows that cross the interface between the SG and facility are summarized in Table B.6.

At ahead time, SG calls for capacity market program (CMP) and notifies a facility the eligible conditions for participating in CMP.

- 1) FEMS reports to facility energy planner, who will consult production planner to assess the feasibility of load reduction options. Then facility energy planner determines the willing quantity of load reduction as capacity resource. As a response, FEMS submits the pre-defined load reduction to SG, here the quantity of load reduction should not be lower than the minimum quantity specified by SG.

SG provides guaranteed payments to facility.

- 2) SG provides guaranteed payments to facility and signs a contract with facility specifying details related with the transaction (e.g., the agreed quantity of load reduction as system capacity, penalty in case of non-compliance). Optionally, FEMS may inform SG that this facility is acknowledged as a candidate DR resource for providing system capacity.

During intra-day, the SG periodically reviews its energy plan, and dispatches a DR event in case SG identifies potential energy shortfalls or anticipates system contingencies.

- 3) SG sends DR signal to the facility to reduce load as contracted previously. Optionally, facility may announce its inability of reducing load to SG. Otherwise, FEMS reports the DR signal to facility energy planner and production planner, who will then order production operator to execute the load reduction after the notification time elapses. Meanwhile, the adjustments to any production plans (see use case FG-200) are also made by production planner accordingly.

SG terminates the DR event and evaluates the demand response performance of facility.

- 4) SG notifies FEMS of the ending of DR event, and also informs FEMS of the actual quantity of load reduction as well as of the corresponding reward or penalty in case of non-compliance. FEMS then informs the facility energy planner and the production planner of the ending of DR, who may inform the facility production operator to recover the load.