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Smart grid user interface

Part 1: Interface overview and country perspectives

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The UK participation in its preparation was entrusted to Technical Committee L/13, Smart Grid policy.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Published by BSI Standards Limited 2014

ISBN 978 0 580 87037 8

ICS 33.200

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This Published Document was published under the authority of the Standards Policy and Strategy Committee on 31 December 2014.

Amendments/corrigenda issued since publication

Date	Text affected

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Full document details: PD IEC/TR 62939-1:2014

IEC TR 62939-1

Edition 1.0 2014-11

TECHNICAL REPORT

colour inside

Smart grid user interface –
Part 1: Interface overview and country perspectives

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE XF

ICS 33.200

ISBN 978-2-8322-1913-3

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SMART GRID USER INTERFACE –

Part 1: Interface overview and country perspectives

FOREWORD

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IEC TR 62939-1, which is a technical report, has been prepared by IEC project committee 118: Smart grid user interface.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
118/40/DTR	118/42/RVC

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

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

A list of all parts in the IEC 62939 series, published under the general title *Smart grid user interface*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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0 Introduction

0.1 High-level definition of Smart Grid user interface (SGUI)

The Smart Grid user interface (SGUI) is a logical, abstract cross-domain interface that supports appropriately secure communications of information between an entity within the customer domain (e.g., home or building energy management system, electrical load, energy storage system or generation source) and an external service provider (e.g., utility, aggregator, market or customer energy service provider). Devices and applications will implement the SGUI between grid-side entities and customers for the purpose of facilitating machine-to-machine communications. The SGUI needs to meet the needs of today's grid interactions (e.g., demand response, grid-aware energy management, electric vehicle (EV) charging equipment interactions) and those of the future (e.g., retail market transactions).

In practice, the SGUI will potentially be one interface between multiple aggregation points, both inside and outside of the customer facility. Implementations will have variations arising from complex system inter-relationships: diverse customer business and usage models with different types of equipment in different types of customer facilities controlled by a range of energy management systems.

0.2 PC 118 history

In 2010, China proposed three new work proposals for IEC standards for Smart Grid user interface. There was a long process (refer to Annex A for details of the history of the establishment of Project Committee 118) of SMB and Strategy Group 3 (SG3) discussions and interaction with different TCs who each were working on some standards efforts related to the customer interface. Because many TCs have some connection to the SGUI, the Project Committee approach was chosen with the goal of coordinating between TCs to move forward toward effective standards. China was appointed secretary of PC 118 and the two Chinese work proposals became two working groups within PC 118, each tasked to produce a standard that would become deliverables of this temporary PC.

PC 118 members first met in Tianjin, China, in February 2012. At that meeting, representatives from different TCs and NCs each presented standards work related to the SGUI. Also at this meeting PC 118 members agreed to prepare a technical report covering the definition of the SGUI, the national requirements for SGUI communications (use cases), and an analysis of standards gaps between requirements and available standards. The end result would be acknowledgement of available international standards, recommendations for advancement of national standards and/or development of new standards to fill gaps.

PC 118 members recognized that standards exist for interactions between the traditional grid domain and the customer domain. There are international and national standards covering different parts of the interface. IEC TC 57 had just established a new working group (WG 21, Interfaces and protocol profiles relevant to systems connected to the electrical grid) and other TCs and WGs address meter interactions, industrial plant interactions, EV communications, market information models, etc. PC 118 adopted the approach of preparing this technical report, welcoming member countries and other IEC TCs to participate.

One may ask where Smart Grid stakeholders derive value. The industry will be best served by rapid progress which in turn is enabled by use of established technologies which meet Smart Grid user interface functional and quality requirements. This technical report presents the work of PC 118 members to gather and report the requirements for the customer interface, available standards, and identified standards gaps. Some national standards are recommended for advancement in IEC.

0.3 Relation of IEC PC 118 to other IEC technical committees

According to the PC 118 Strategic Business Plan (SBP) (SMB/4823/R, June 2012), the scope of PC 118 is to look at information exchange between the customer and the power grid from the user's point of view. PC 118 draws on the input of other IEC TCs to have a coherent IEC

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perspective on the customer interface, developing a set of standards (or mapping to existing standards) to ensure that IEC standards meet the needs of customer Smart Grid interactions. In order to do this, PC 118 works with IEC TCs developing standards for the power grid and within the customer domain.

IEC TC 57 is the manager of the IEC Common Information Model (CIM) and 61850 standards that serve as the information models for power grid domain communications. TC 57/WG 21 is specifically focused on the customer interface from the power grid point of view. IEC TC 13 developed the standards of the IEC 62056 Device Language Message Specification (DLMS)/ Companion Specification for Energy Metering (COSEM) suite [1] [1] for the purposes of electricity metering.[2] The PC 118 SBP scope is, "Standardization in the field of information exchange for demand response and in connecting demand side equipment and/or systems into the Smart Grid." Also, "PC 118 will develop a harmonized and consistent suite of standards for the users." PC 118 will work with existing IEC, ISO standards and examine existing national standards in order to identify the collection of standards that together meet the needs of the Customer Smart Grid interface.

The PC 118 SBP specifically states, "Smart Grid user interface related standards prepared by other technical committees of the IEC (including IEC/ISO JTC1) shall be used where applicable. PC 118 shall apply analytical approach and Use Cases developed by IEC TC 8 for Smart Grid requirements. PC 118 shall use IEC CIM and IEC 61850, and will develop new information models in view of demand side needs and characteristics. PC 118 shall consider IEC TC 57, TC 13, TC 59, TC 69, TC 72, TC 100, IEC/ISO JTC1 SC 25, TC 56, TC 65, etc., related architectures and standards. PC 118 should also consider Smart Grid user interface related standards prepared by other organizations such as ISO and ITU."

0.4 Report overview

Clause 2 introduces the customer (the Smart Grid user) interface—an interface between separate and historically independent domains. Subclause 2.3 presents a high-level conceptual model for demand response interactions from loosely coupled market interactions down to direct load control interactions. Subclause 2.4 organizes the functional requirements that have been discussed in PC 118. The remainder of Clause 2 examines the SGUI architecture, actors, and quality requirements.

Clause 3 begins with an overview of PC 118 member country perspectives on SGUI and an overview of contributed use cases (details in Annex C). Subclause 3.4 presents an analysis of use cases organized according to the functional requirements in 2.4. Subclause 3.5 looks at the relationship of SGUI to advanced metering infrastructure (AMI) and electric vehicles.

Clause 4 examines existing standards relevant to the use case classes to identify standards that meet the needs of the SGUI, or alternatively to identify gaps in IEC standards. This in turn informs Clause 5 recommendations for IEC SGUI standards development work.

0.5 Key recommendations and findings

PC 118 has identified some gaps in international standards for each of the use case classes presented in 4.4. Several existing national standards are recommended for advancement in IEC. Discussion of recommendations can be found in 4.5 and Clause 5.

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1 Numbers in square brackets refer to the Bibliography.

2 The COSEM data model is also used by other Technical Committees responsible for non-electricity metering.

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SMART GRID USER INTERFACE –

Part 1: Interface overview and country perspectives

1 Scope

This part of IEC 62939, which is a technical report, presents an international consensus perspective on the vision for a Smart Grid user interface (SGUI) including: SGUI requirements distilled from use cases for communications across the customer interface (the SGUI); an analysis of existing IEC and other international standards that relate to the SGUI; and an identification of standards gaps that need to be filled and might become potential work items for IEC Project Committee 118.

The PC 118 scope is, *"Standardization in the field of information exchange for demand response and in connecting demand side equipment and/or systems into the Smart Grid"*. This report presents the information exchange and interface requirements leading to standards to support effective integration of consumer systems and devices into the Smart Grid.

2 Smart Grid user interface overview

2.1 SGUI – Consensus perspective

The title and scope of IEC PC 118 refers to a "user interface." This term can have multiple meanings and interpretations. In the context of the work of PC 118 a "user" is some entity (actor) that consumes electricity supplied by the electric grid, or some distributed energy resource, such as storage or local generation that might produce energy. A user can be considered as a home, a vehicle, a commercial building, an industrial plant, or some system/device within a customer facility [3]. A "user interface" is a means to exchange information between the electric grid service provider and the user.

This Smart Grid user interface (SGUI) is not designed to be a human-machine interface, but may supply information to aid such an interface. It does not presume any particular communication or control technology that might be deployed by the user within a facility to react or respond to the information exchanged, and does not presume a single communication mechanism between actors on the grid and facility sides. It provides a basis for information exchange between the energy service provider or other grid-side entity and the customer-side entity, and nothing more. A high-level view of the SGUI is shown in Figure 1. In this simple figure, "Grid operations" also includes markets and energy service providers (see also 2.4 for SGUI functional requirements, 2.5 for SGUI architecture and 2.6 for example of actors within grid operations and customer facility management and control).

[3] A "facility" is used in this report to refer to homes, buildings and industrial plants.

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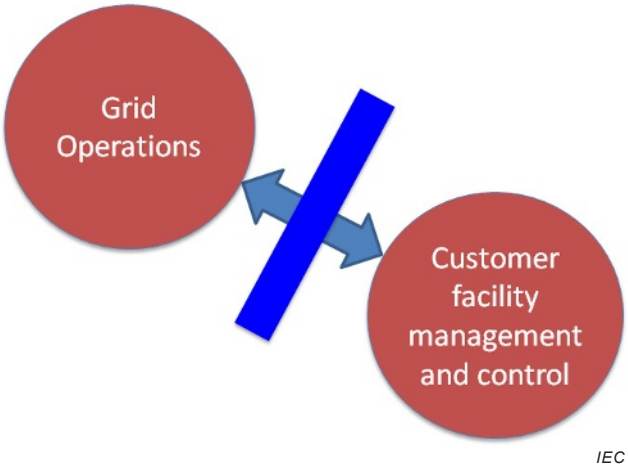

Figure 1 – High-level view of the SGUI architecture as interface (blue line) between different domains

The SGUI serves as an interface between two different domains that exist and evolve independently, and have developed over time with different information models and communication protocols. The SGUI serves to connect these domains: the "grid" domain (all those entities directly involved in the operation of the traditional electric grid) and the "customer facility" domain. The SGUI "user" is a more abstract term for the customer facility, since the "user" can be the same as the customer facility, or some system/device within the domain, or even an aggregation of systems.

The information communicated across the interface may include: demand response signals, price signals, load parameters (e.g., demand, forecast demand, storage availability), market transactions, energy usage (meter data), emergency signals broadcast by system operators, and other energy-related parameters such as power quality [2]. No single interface is required to communicate all of these things. For example, a simple residential gateway may possibly receive only price, or a meter may possibly report only energy usage information[4].

The SGUI may on the one hand be a high-level interface passing data such as price and DR event signals or meter usage data to be interpreted by the customer facility, or it may on the other hand be a low-level device interface which commands device operation based on the grid-side operational needs. In the first case, the interface is more abstract, with information communicated to enable any user devices, systems, or sub-systems within home or building to take actions. In the second case the interface is at the system or device level and may expose specific controls[5]. The kind of interface is determined by the specific requirements. In order to promote customer choice, scalability, flexibility and security, it is better in general to have a higher-level interaction.

In practice, the SGUI will be one interface within a hierarchy consisting of potentially multiple interfaces which may include aggregation, both inside and outside of the customer facility. Implementations will have variations arising from complex system inter-relationships: diverse customer business and usage models with different types of equipment in different types of customer facilities controlled by a range of energy management systems.

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4 The ISO/IEC 15045 series [3] specifies options for gateway features that extend beyond communications protocol translation between a wide area network and a local area network.

5 ISO/IEC 15067-3 [4] specifies these levels of interaction including the "abstract" level where price or event data are sent to a local Energy Management Agent that interacts with local devices.

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2.2 Inter-domain interoperability

2.2.1 General

The Smart Grid is composed of multiple domains, each with systems that together coordinate between all the actors of the electrical power system to provide reliable power to customers. SGUI includes the standards that connect actors in the grid domain (service providers, operations, markets) to customer systems (the Smart Grid "user"). Each domain has existing information models with invested equipment using existing communication protocols. The challenge is to bridge the different domains to accomplish SGUI functions (meeting SGUI use case requirements). Subclause 2.2 reviews some key principles of cross-domain interoperation. SGUI standards shall adhere to these principles.

Interoperation across domains typically involves components that are managed by different organizations. Organizations maintain autonomy while collaborating and sharing their resources. These relationships are governed by a set of principles described in the GridWise Interoperability Context-Setting Framework [5], which clearly establish rules for interoperation as shown below.

2.2.2 Agreement at the interface – a contract

As in any business engagement, the associated parties establish the ground rules and capture them in a contract or an agreement. Each party exchanges goods and services as an independent entity. The terms and conditions describe how goods and services flow between parties, the price, the scope, the schedule, and the quality of the deliverable. They also describe the consequences for failure to perform. They rarely state how the good or service is created or obtained.

Similarly, we presume that agreements between components concentrate at the place where the boundaries of each component meet – their interface. By establishing an interface agreement, each component preserves its integrity. It can change internally and react to various pressures independent of other components as long as it meets its interface agreements.

2.2.3 Boundary of authority

In the electric system, resources are aggregated in a hierarchical fashion, for example, from the demand side (customer facility), to the distribution feeder, transmission substation and network control. Each component of such a system plays a role with appropriate authority to do its job. Constraints, rules, or regulations may be specified to which interface agreements shall conform. How such authority is bestowed is a regulatory, political, and business policy decision.

The boundary of authority includes addressing rights of privacy and disclosure and run-time expectations. To the greatest extent possible, any constraint or restriction should be reflected in the interface agreement between interacting entities so that internal decisions for how a constraint or restriction is met remain within the boundary of authority of each interacting party.

2.2.4 Decision making in very large networks

As systems grow, common approaches are to federate systems with similar scope. The Smart Grid is a system of systems, where each system has its own models, rules, and implementations. System federation addresses issues of customer, grid, bridging, and diverse management approaches, and enables working together across individual organizations, subsystems, and persons acting in their own best interests while setting up information mechanisms to influence decisions that benefit all participants [6][7].

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2.2.5 The role of standards

Standards are extremely important tools to improve interoperability. For a standards specification to have impact, however, it needs to be available to its potential users. Proprietary standards may only be available to a community that purchases a specific product. Open standards can encourage a competitive, multi-supplier environment. Allowing multiple solution suppliers to compete encourages innovation in features and performance. Openness implies that there is adequate information to ensure equal opportunities to produce compliant components from independent suppliers. The European Information and Communications Technology Industry Association offers the following criteria for openness [8]:

- Control: The evolution of the specification is set in a transparent process open to all interested contributors.
- Completeness: The specification is complete (within its scope) to ensure interoperability.
- Compliance: There is a substantial standard-compliant offering promoted by proponents of the standard.
- Cost: Fair, reasonable, and non-discriminatory access is provided to intellectual property unavoidably used in implementation of the standard.

2.3 Smart Grid user applications

2.3.1 General

Subclause 2.3 covers possible applications involving the Smart Grid user interface. One key application for SGUI is demand response (DR), as defined below. Demand response (and other SGUI applications) may include customer use of storage and generation resources behind the meter to reduce energy usage measured at the meter. Customers may respond to price signals, DR event signals, or control signals, to provide flexibility [9] to the grid.

2.3.2 Demand response

2.3.2.1 General

Demand response refers to changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.

2.3.2.2 Levels of demand response interactions

2.3.2.2.1 General

The electric industry and customers have implemented various methods of demand response. ISO/IEC 15067-3 [4] divides these methods into direct and indirect load control that may convey control and price signals. We can categorize these methods into four distinct hierarchical levels of interactions as shown in Figure 2.

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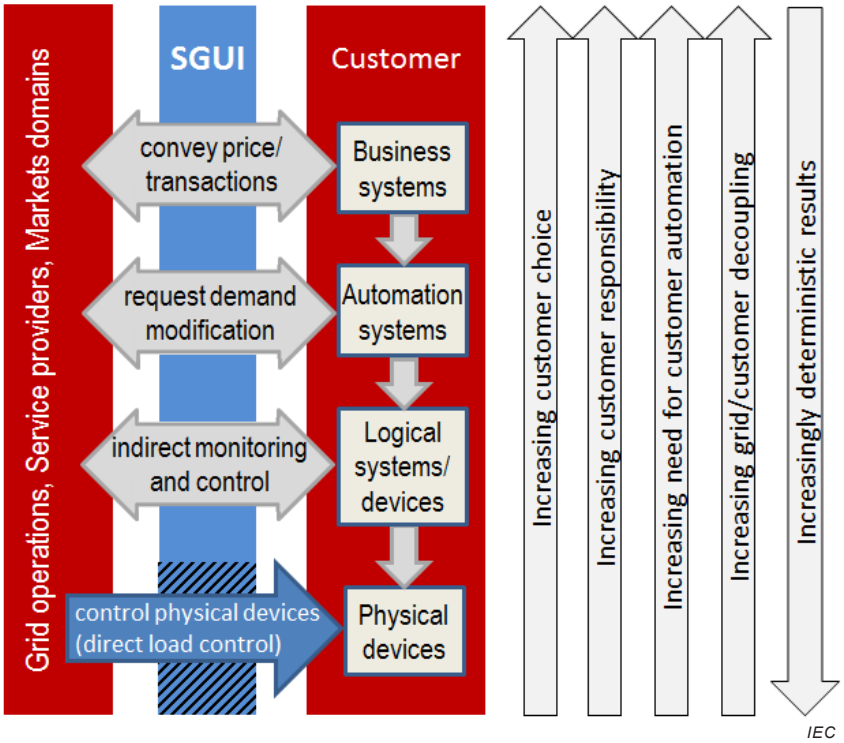

Figure 2 – Levels of demand response interactions

DR signals are passed from a DR service provider (left side of Figure 2) to a customer (DR resource), and there may be feedback. The four levels of DR interactions are shown in the arrows crossing the SGUI in Figure 2, and are discussed below. The levels represent the different kinds of signals (information and purpose) sent to different customer systems/devices with varying level of benefits to the customers and service providers. The long vertical arrows on the right show the changes in the nature of the interaction across the SGUI at different levels. The level of DR interaction determines the kind of signals communicated, the amount of automation required in the customer facility, the amount of customer control over response versus DR provider control, and the degree to which device action is deterministic. Each approach has its advantages and disadvantages as discussed below.

The question was raised in PC 118 as to the definition of direct load control and whether it belongs in the SGUI functional requirements. Direct load control (DLC) is defined below in the discussion of level 1. Its place in PC 118 is discussed in the use case analysis (3.4).

2.3.2.2.2 Control physical devices (level 1)

At the lowest layer of DR interaction, the energy service provider directly controls devices and the power to the load. An example of this is the use of a radio frequency signal to trigger relays on air conditioning units.

The term “direct load control” is often used to refer to a DR service provider (e.g., utility) switching on or off customer systems, devices, or appliances. For example, signals from a utility or a third-party service provider may directly control home air conditioners and hot water heaters. DLC is widely used with residential customers and ISO/IEC 15067-3 defines DLC in the residential context as “remote control of one or more appliances by a utility or third-party service provider”.

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Advantages/disadvantages:

- The energy service provider needs to understand how the load operates as well as the device type in order to turn power on and off directly and how this affects safety, reliability, environment, comfort, etc.
- Low-level physical control is often the lowest cost in the absence of existing automation equipment.
- The customer has no risk or control for whether the load is actually controlled as directed by the energy service provider.

2.3.2.2.3 Indirect monitoring and control (level 2)

At the next level of DR interaction, the utility uses the customer's automation equipment (thermostat, building management system, etc.) to send device-specific (or sub-system-specific) signals to change the load.

At this layer, there is control logic between the utility and the load. The utility requests an action to occur on a logical device or system. For example, an energy service provider might send a signal to a thermostat to increase/decrease temperature set points. Higher priority requirements in the control logic may override the signal from the utility, e.g. safety overrides or equipment reliability considerations.

Advantages/disadvantages:

- Energy Service Providers do not require full knowledge of the devices in the customer domain, because the automation system ensures that appropriate facility and equipment constraints are maintained.
- The customer requires a minimum level of automation capability depending upon what devices are being controlled. This may increase cost if new automation equipment is required, for reasons such as the ability to communicate with the Energy Service Provider.
- Energy Service Providers wishing to come in at this level may need to interface with automation and control protocols used by existing systems.
- Security and privacy concerns may require additional costs in order to address the associated risks.
- Changes in the customer’s automation equipment can impact the Energy Service Provider.
- The customer is only responsible for doing what was requested and not for whether what was asked is sufficient to achieve the needed demand reduction.

2.3.2.2.4 Request demand modifications (level 3)

At the next level of DR interaction, the DR Service Provider specifies the desired results and the user decides how to achieve those results, e.g. "Reduce/Increase your load by 10 kW."

At this level the user or the user’s automation systems decide on the optimum course of action, based on an analysis of the trade-offs, to achieve the desired results with the minimum impact on the user.

Advantages/disadvantages:

- The customer is fully responsible for achieving the agreed upon reduction in demand.
- The Energy Service Provider is not impacted by customer-side equipment changes or automation strategy changes.
- The customer has a choice on what it will curtail in order to achieve the requested results.

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- The Energy Service Provider does not require knowledge of the exact details of how the user will respond internally, only the overall result.

2.3.2.2.5 Convey prices / transactions (level 4)

At the highest level of DR interaction, the DR service provider conveys a price or a price is negotiated and the user decides what to do. At this level, the user or the user's pre-programmed automation systems decide on the optimum course of action to achieve the best results consistent with the user's business goals.

Advantages/disadvantages:

- The customer determines price risk and potential savings.
- The customer has a choice on how, or whether, to respond to the price signals.
- Advanced automation strategies may be required to take advantage of dynamic prices while minimizing risk.

2.3.2.2.6 Interactive DR versus DLC

Figure 3 may be helpful in understanding the distinction between indirect or "interactive DR" (levels 2 to 4) and DLC (level 1) and the customer role. DLC is equivalent to circumventing any local customer control over a customer device; a DR service provider directly controls the power to the customer device. On the other hand, interactive DR includes some measure of customer control in varying degrees. Interactive DR may also imply customer feedback (bidirectional communications), which is required for certain DR use cases.

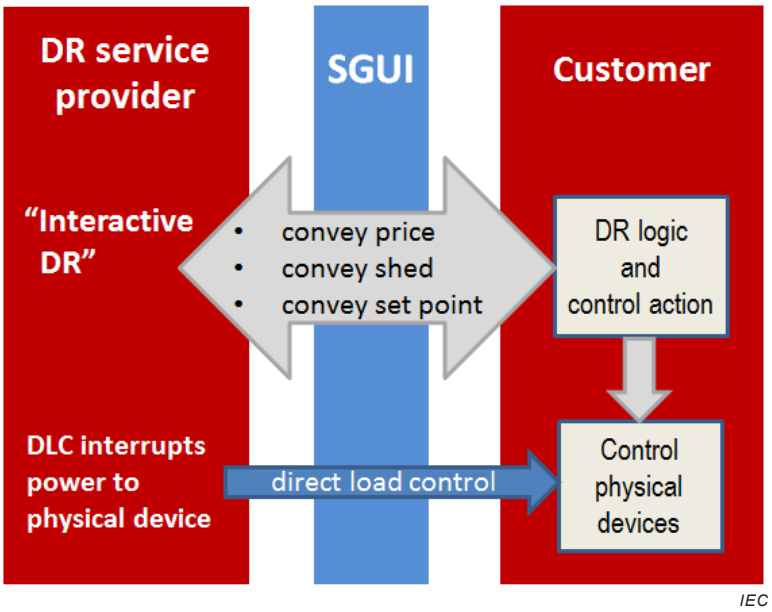

Figure 3 – Interactive demand response versus DLC

2.3.2.3 Characteristics of moving to higher levels of DR interaction

2.3.2.3.1 General

There are several characteristics that tend to emerge as demand response solutions move to higher levels of demand response interaction. These are shown as vertical arrows on the right side of Figure 2.

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2.3.2.3.2 Increasing customer choice (characteristic 1)

At lower levels of demand response interaction, the user may have no control over when the DR service provider curtails their loads. This may cause problems with customer satisfaction and willingness to participate in demand response programs. It can also affect equipment reliability. At higher levels of demand response interaction, customers can decide how to achieve the desired demand reduction or whether financial or other considerations override the request from the Energy Service Provider. This can increase customer satisfaction and willingness to participate in demand response programs.

2.3.2.3.3 Increasing user responsibility (characteristic 2)

At lower levels of demand response interaction, the DR Service Provider is responsible for installation and maintenance of all equipment and connections used to control the response to the demand response event. The DR Service Provider is also responsible for all demand reductions which are achieved or not achieved as a result of system problems. At higher levels of demand response interaction, responsibility for installation and maintenance of facility equipment that is used to control the response to the demand response event shifts to the customer. The financial benefits and risks of participating in the demand response program also shift to the customer.

2.3.2.3.4 Increasing need for user automation (characteristic 3)

At lower levels of demand response interaction, the user is not required to have any automation equipment since the DR Service Provider directly controls whether power is allowed to flow to the load. The need for automation increases as demand response shifts to higher levels of interaction. At the level just above direct load control, this may be as simple as a thermostat. Higher levels of interaction may require a building management system, energy management system, or even some type of enterprise level system that considers trade-offs between energy prices and other business considerations.

2.3.2.3.5 Increasing grid/user decoupling (characteristic 4)

Users often have a significant investment in automation equipment for their facilities. They will not automatically replace existing automation equipment to communicate with the Smart Grid. Instead, they will evolve their existing systems to include this functionality.

Facilities do not need to have as complete of an understanding of the grid as grid domain participants require. The grid operator does not need to have as complete of an understanding of all facilities as operators of these facilities require. The SGUI can serve as a decoupling mechanism that allows these two domains to interoperate without being too closely tied together.

A stable interface promotes decoupling and enables changes to occur on either side of the interface. This minimizes the impact of these changes on the other side of the interface. Stability does not automatically require a static interface, but it does require that changes to the interface shall be made in a way that does not break existing, deployed systems.

2.3.2.3.6 Decreasingly deterministic results (characteristic 5)

At lower levels of demand response interaction, the resulting demand reduction can be very deterministic since the energy service provider is directly disconnecting the power to the load. At the higher levels of demand response interaction, the resulting demand reduction is more indeterminate unless aggregation of numerous demand response resources is included. Aggregation converts a collection of indeterminate resources into a determinate resource for the grid.

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2.3.3 Other SGUI applications

SGUI applications include but are not limited to demand response. While demand response and related functions discussed above relative to Figure 2 are key functions of the SGUI, other use case functions have been identified, as seen in 2.4. These functions include: information communication such as meter reading (energy usage information), equipment energy efficiency management, power quality monitoring, and notices of imminent power failure. Also, ancillary services are not traditionally considered demand response.

2.4 SGUI functional requirements

Subclause 2.4 presents a summary of the requirements based on use cases that are reviewed in 3.3, and based on discussions in PC 118 that have focused the SGUI perspective down to a cross-domain interface as shown in Figure 1. There are some requirements expressed in use cases reviewed that seem to be more like edge cases for the SGUI, and which may or may not be clearly captured in the following functional requirements classifications. These edge cases are not being completely dismissed, but may be of lower priority, or may be re-examined.

Functional requirements are derived from business use cases and define the system functions—what the system should do. Quality requirements (2.7) address the performance requirements including SGUI testing requirements based on the use cases. The architecture (2.5) defines the structure of the system to meet the requirements.

Use cases can be summed up in terms of the following information exchanges (functional requirements list below). Not all users (e.g. residential devices versus large facility energy management systems) need to support all of these functions since the programs and the capabilities of systems can vary greatly.

This technical report, guided by the submitted use cases, addresses the important present areas of: demand response, price-based interoperation, and direct load control. In addition, monitoring, confirmation of delivery and demand, and other reporting capabilities are important. In 3.4 we present a detailed analysis of the use cases; the following functional requirements are in the same form and order as the use case classes of Clause 3.

Functional requirements for the smart grid user interface include the following:

1. Interact with markets: This requirement implies the communication of market prices and product descriptions, and the ability to respond to price information. Market transactions between the grid and the user are used to buy or sell electricity under terms that can be negotiated using the interface. Market transactions require a client that knows its forecast demand or generation in order to place bids and offers into a market.
2. Convey price and product description[6]: This includes fixed, scheduled, or real-time varying prices for electricity provided by the grid and consumed by the user, or vice versa. Prices may address a diverse range of electricity market products which will continue to evolve. Price information shall include product description. In some cases prices may be determined through a negotiation process that needs to be part of the interface.
3. Convey ancillary services and operator signals: This includes voltage regulation and real-time dispatch.
4. Convey demand response and distributed energy resource (DER) requests and notifications: This involves asking the user to shape electricity demand on a temporary basis and may be done through price changes or by invoking a previously agreed upon

[6] As described in the NIST Smart Grid Framework and Roadmap [10], price without product definition (to which the price applies) is insufficient.

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response to a DR event signal[7]. Here we refer to an abstract interface where the energy provider does not control the load and relies upon the user to respond in an appropriate way (per contract) to the information provided. DR requests include those for emergency DR.

5. Convey indications of impending power failure or grid instability: This does not include communication of natural disaster or weather related events, but does include notifications of impending power failure or grid instability that may result from natural disasters, weather, or other events.
6. Convey directed interaction requests: This includes direct load control actions applying to users who do not have the ability to respond to price signals or demand response requests but have entered into an agreement to permit the energy supplier to directly modify or shut off individual loads. Related areas include directed management of energy storage resource; such requests may be expressed in terms of either power, energy or charge state of the resource.
7. Convey historical or real-time energy usage (meter measurements): This involves providing a way for a user to supply aggregated, whole building, systems, or sub-system energy usage information to the energy provider, which can be used to meet DR program participation requirements and assist in measurement and verification of the participating user. The same software mechanisms can convey forward power usage projections, providing a way for a user to supply forecast information to the energy provider that can be used to manage grid resources, and be useful for evaluating and measuring energy efficiency and for facility commissioning and green building/LEED continuous commissioning. The energy provider may also provide validated energy usage data to the user. Demand is more specific and is included in the next class.
8. Convey monitoring information: Monitoring is key to demand response and distributed energy resource management and verification, as well as energy efficiency information with respect to the Smart Grid user. Information that may be monitored includes storage and generation availability, status, present and forecasted demand and capacity, and other forecast information to enable effective management of the grid. Usage forecasts are addressed in item g). Measurement of energy usage at a transfer boundary is important for monitoring and verification. Power quality may be monitored, although perhaps by other interfaces. Compared to item g) above, monitoring suggests more extensive data collection and interaction than simple usage (historical, present, and future projections).

In addition, some submitted use cases present functionality that provides remote facility management for systems internal to the customer/Smart Grid user, such as remote health monitoring, which seems specific to facilities and their implementations, and subject to future independent evolution.

DR and DER events, as well as ancillary services and market interactions require supporting services and information. This might include: registration, enrollment, communicating the availability of resources, opt-in or opt-out responses to DR event signals, status of load response, and appropriate baseline data.

The following figure (Figure 4) shows the information flowing across the SGUI and some actors on either side. The information is represented in the blue arrows. The architecture of the SGUI will be discussed more in 2.5. Actors are discussed in more detail in 2.6.

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7 This agrees with the more simple definition of DR given in IEC 60050-617-04-16 [11], “action resulting from management of the electricity demand in response to supply conditions.”

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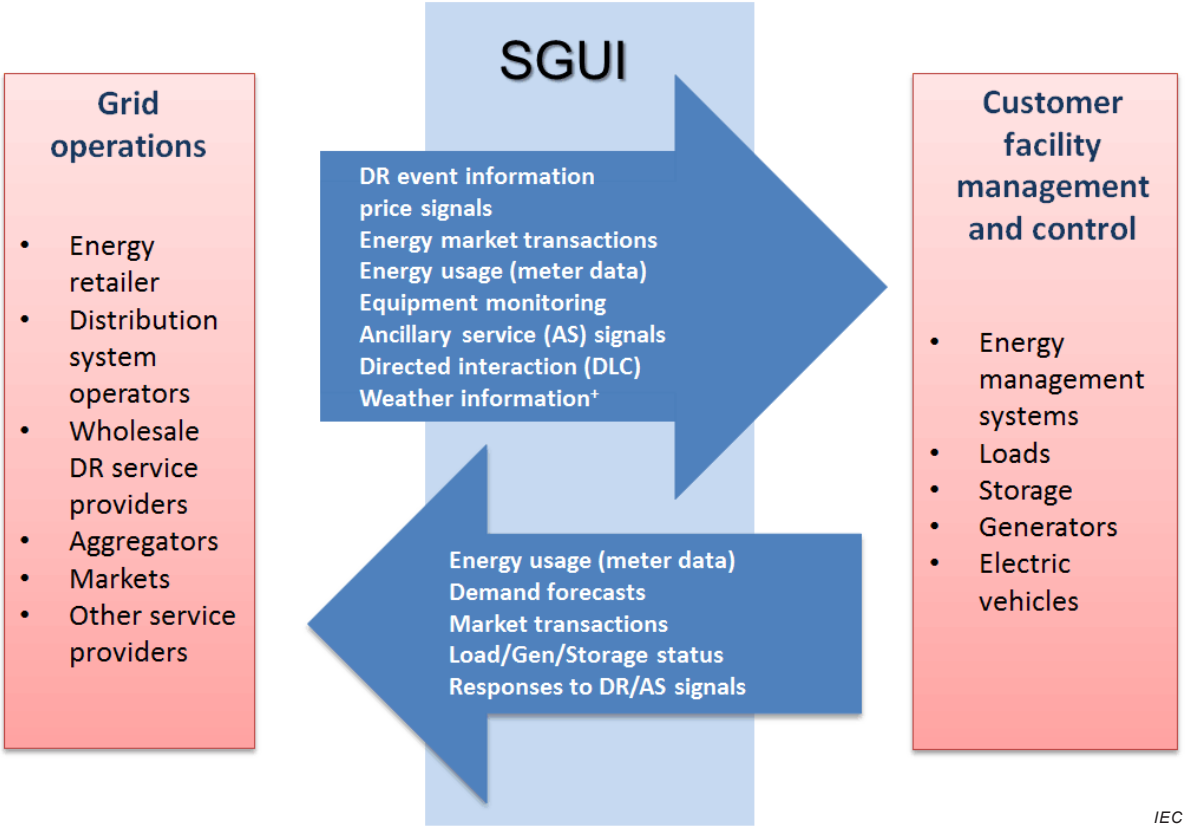

NOTE Weather information is important for Smart Grid, but is not listed as an SGUI functional requirement in 2.4. International standards (e.g. WXXM in WMO) cover this, and weather services already provide weather data.

Figure 4 – Information exchange through the SGUI between the grid (external service providers) and users in the Customer Facility domain

2.5 Architecture

The goal of 2.5 is to understand how the SGUI fits into a Smart Grid architecture, by discussing the goals of the architecture and a conceptual reference model.

The SGUI shall be suitable for interaction with many different kinds of users with varying abilities and constraints. The control and automation technology used to respond to the grid communication will vary with the type of user (residential, commercial, industrial). The Smart Grid user interface shall work with all of them. It is important that changes in the control technologies found in the user's facility do not "break" the interface. These control technologies will evolve on independent time schedules. This means that the architecture for the interface shall be based on specific communication exchanges that do not depend on the details of how the user implements a response. The interface serves to abstract the details behind the interface in order to promote scalability, extensibility, and flexibility. The proper level of abstraction provided by the interface will vary based on the business and application requirements.

Because of the possibility of aggregation of users, a single entity (e.g., an aggregator) may look like a user to an energy service provider but at the same time look like an energy service provider to one of the aggregated users. The architecture shall accommodate this type of hierarchical structure.

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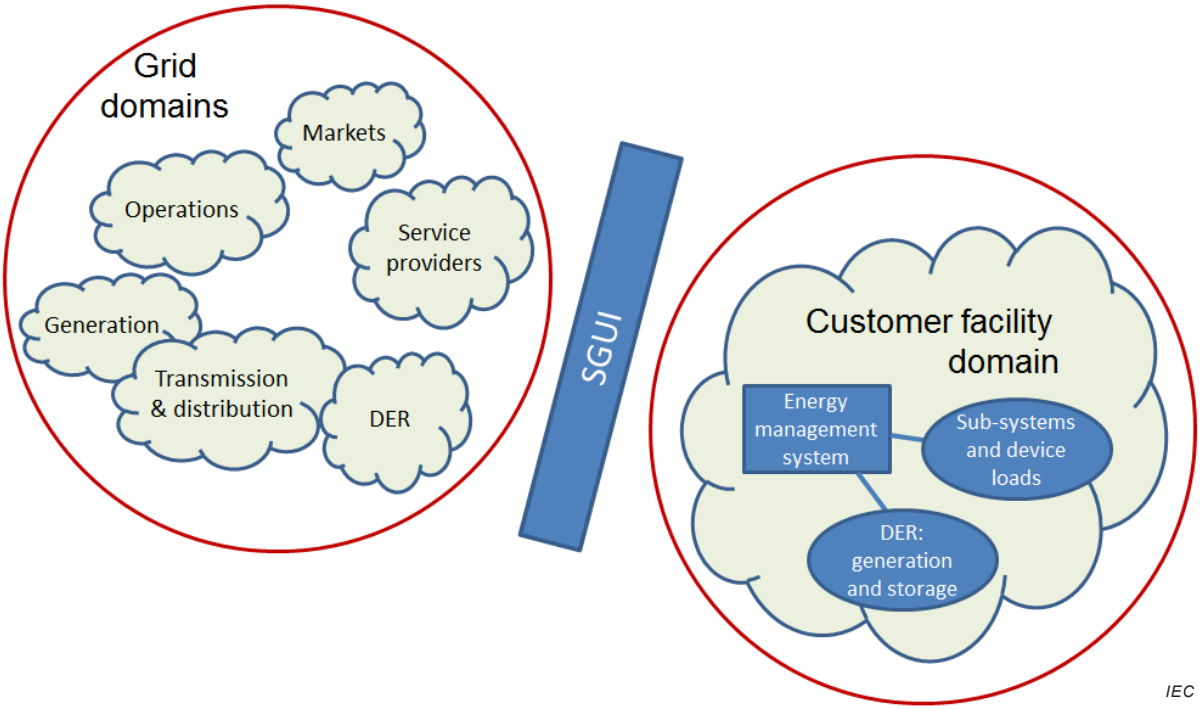

Figure 5 – High-level generic Smart Grid user interface architecture

Figure 5 shows a conceptual diagram of the different Smart Grid domains and the interactions with the customer facility domain. The customer facility domain is seen to interact directly with service providers (and other grid-side domains) via the SGUI. All communications to the customer domain pass through an SGUI, whether that interface is used for communications to an energy management system (EMS), or to a specific piece of equipment (direct load control). The SGUI functions can be hosted by a dedicated device such as a residential gateway or added as a functional component inside an existing device such as a smart meter. In particular, a smart meter may be used to support a subset of SGUI functions in order to ease deployment of services without needing to deploy new hardware components inside the premises. An example architecture for residential applications with direct interactions through the meter is provided in 3.2.4 based on French implementation.

The ISO/IEC 15045 [3] series of standards specifies a gateway as a logical demarcation between the public and private domains. The SGUI may be included in the gateway, in an EMS (energy management agent, specified in ISO/IEC 15067-3 [4]), or at end-devices within the premises. The choice depends on implementation design, complexity, and market factors such as product configuration and cost.

In Figure 4 we see that there are two sides to an SGUI: the “grid” side and the “customer facility” side. The grid side is exposed to the energy service provider (or an aggregator), while the facility side is exposed to customer systems. The SGUI represents a logical demarcation point of ownership or an operations support boundary. A clear demarcation encourages market developments of competitive devices, equipment and appliances that facilitate demand response, energy efficiency and energy management.

An SGUI may be owned and operated by either an energy service provider or a customer. The physical location is of minimal importance. The number and structure (hierarchy) of SGUIs will vary as determined by service providers and customers.

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2.6 Actors

2.6.1 Overview

An actor is a device, computer system, software program, or the individual or organization that participates in the Smart Grid. Actors may take on various roles. Actors have the capability to make decisions and to exchange information with other actors. Organizations may have actors in more than one domain. The grid service providers and customer facility users illustrated in Figure 4 are representative examples but are by no means all of the actors relevant to the Smart Grid user interface. Each actor may exist in several different varieties and may actually contain other actors within them.

2.6.2 Customer domain characteristics

The customer facility domain has varying degrees of complexity—the residential home is relatively simple while large commercial and industrial facilities can be very complex. Each sub-domain (residential, commercial, industrial) has multiple actors and applications. The communication technologies and standards used by devices in the different sub-domains vary significantly.

The diverse energy assets within the customer domain can be characterized by: electrical capacity, operational characteristics, economic impact on customer, operational flexibility of customer, operational impact on the electric system, system complexity of customer, level of customer automation, customer sustainability needs, and energy assurance needs.

2.6.3 Grid-side, customer-side, and SGUI actors

2.6.3.1 General

We divide actors into three categories:

- grid-side
- customer-side
- SGUI (at the boundary between the grid and customer sides)

Some actors are at the boundary, specifically, metering and gateway functions. The purpose of 2.6.3.2 to 2.6.3.4 is to show example assignments of actors; this is neither exhaustive nor prescriptive.

Metrology and metering are listed as grid-side actors, but also as actors in the customer-side; we include them in both lists as well as the SGUI list, as metering flows between the grid- and customer-side are an SGUI function.

2.6.3.2 Grid-side actor examples

Grid-side actors include markets, utilities, systems and transmission operators, energy services companies (ESCOs), energy management providers, aggregators, etc. The lists below are not meant to be exhaustive.

Market domain actors include:

- Retailer/wholesaler—Wholesaler or retailer purchasing energy in the market and selling it.
- Aggregator—Service provider aggregating small-scale participants (supplier, consumer, load shedding/reduction) and performing transactions for them in the electricity market.
- Energy market clearinghouse—Market operator or system deciding the electricity market price based on the bids of consumers and suppliers in the electricity market and the collected information on the electricity system operation, and calculating the charges for the services supplied by the market participants

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Operation domain actors include:

- EMS—Comprehensive energy management system that monitors and controls the operation of the electricity system in real time, produces electricity in an economical way, and supplies electricity in a stable manner.
- DMS—Distribution management system that analyses the operation of the distribution system and operates it efficiently.
- MDMS—Meter data management system that stores and manages the energy use data or events measured by AMI/AMR.
- DRMS—Demand response management system that manages the amount of energy used by customers according to the demand/supply state.
- OMS—Outage management system that assists in the restoration of power to the customers.
- GIS—Geographic information system that captures, stores, manipulates, analyzes, manages, and presents all types of geographical data including the customer locations.
- TCM—Trouble call management system that offers better customer service by reducing interruption time.

Service provider domain actors include:

- Retail energy provider—Energy service provider (retailer) with its own customer information system and billing system.
- Home/building manager—Energy manager who manages and installs Smart Grid interacting equipment in homes or buildings.
- Aggregator—Service provider aggregating small-scale participants (supplier, consumer, load shedding/reduction) and performing transactions for them in the electricity market.

Generation and DER domain actors include:

- Generators—Generation equipment and distributed energy resource equipment may participate in markets and receive dispatch signals from grid operators.

Transmission and distribution domain actors include:

- TSO—The transmission system operator manages transmission of electrical power from generation plants over the electrical grid to regional or local electricity distribution operators.
- DMS—The distribution management system monitors and controls the distribution network to improve reliability and quality of service by reducing outages and outage time, and maintaining acceptable frequency and voltage.

2.6.3.3 User-side actor examples

User side actors might include devices, smart appliances, transactive parties, EMS, buildings, microgrids, etc.

DER domain actor examples:

- DER-EMS—Comprehensive energy management system that monitors and controls the distributed energy resource equipment and distributed energy storage system to produce and supply electricity in an economical, stable manner.
- Distributed generation—Distributed energy resource equipment.
- Energy storage systems—Distributed energy storage system.
- Microgrids—A self-managed sub domain with resources and loads.

Transportation domain actor examples:

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- Electric vehicle—Plug-in hybrid/electric vehicle that consumes, stores, and supplies energy.
- Electric vehicle supply equipment (EVSE)—Charging station for EV.

Customer domain actor examples:

NOTE Gateway and metering functions are considered to exist between the grid and customer side; they are listed here and separately in the SGUI actors.

- Residential gateway—Customer side device or application that functions as the communication gateway between the customer devices and actors outside the customer facility domain. A residential gateway may provide gateway functions for energy management. If the gateway provides no other services, such as TV or Internet access, it is equivalent to an energy management gateway. Some electric utilities use the term energy services interface for an energy management gateway (ISO/IEC 15067-3:2012, 3.1.11).
- Meter—Smart meter in the consumer domain; measures the amount of electricity used and possibly generated and may play the role of a communication gateway.
- Customer subscriber equipment—Subscriber's equipment provided by the service provider and connected with the network; (e.g., terminal, set top box, and cable modem).
- Appliances—Home appliances such as air conditioners, heaters, refrigerators, and clothes washers.
- Thermostat—Automatic temperature regulator.
- Customer EMS—Energy management system of home, building, plant, etc. that may monitor and control the operation of electricity distribution, production, and storage within a home or building possibly in real time to achieve the goals of the occupants. These goals may be based on costs, desires for specific device operation (heating, cooking, lighting, etc), or agreements with an energy service provider. Residential EMS types and functions are specified in ISO/IEC 15067-3.
- Customer substation—Substation installed in the consumer's facility.

2.6.3.4 SGUI actor examples

The SGUI in Figure 1 is between the grid-side and customer-side; in 2.6.3.4 we list actors relevant to the SGUI. Logically, these are between the grid and customer, and are essential to carrying out functions related to the SGUI, and can be for example:

- Energy Services Interface—Device or application that functions as the communication gateway between the customer-side actors and the grid-side actors. Some gateways may extend beyond energy, e.g. for telecommunications, cable television, and the like. Some electric utilities use the term energy services interface for an energy management gateway (ISO/IEC 15067-3:2012, 3.1.11).
- Meter—Smart meter in the consumer domain; measures the amount of electricity used and supplied.

NOTE Another vision of these actors considered as functional components is described in the French COSEI Architecture provided in 3.2.4.

2.7 Quality requirements

2.7.1 General

Subclause 2.7 presents the quality requirement topics that shall be considered for any given implementation of an SGUI, in order to meet use case requirements. Application quality requirements include security, reliability, scalability, performance and maintainability. These directly impact system architecture and design.

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2.7.2 Security and privacy

Cyber security is critical due to the potential for adverse impact on both the customer and the power system. Signals sent to or from large numbers of customers represent an attack surface that has the potential to disrupt the bulk power system. Invalid signals from the grid-side sent to the SGUI can interrupt and compromise commercial and industrial operations and may result in harm to equipment and personnel. Invalid signals sent from customers to service providers may cause misinformation and result in potentially harmful actions.

Security enables protected interaction and is fundamentally concerned with managing risk. Security measures shall address application vulnerabilities and exposures, as evaluated by domain experts at the time application requirements are developed. Security in the marketplace requires transactional transparency to ensure auditable and traceable transactions.

Security measures should be tailored to the application. A single security regime does not apply everywhere. The security equipment and operational costs should be appropriate for the environment, threat, and potential consequences. Some data, such as published electric rates, may not need to be encrypted. Rather, customers need to be assured that the data are authentic, meaning the sender is the energy services provider. Such authentication is widely used in Internet commerce.

The six areas of security that need to be addressed by applications are: authentication, authorization, confidentiality, integrity, non-repudiation and auditing. Authentication refers to validating the identity of a user or code. Authorization refers to validating the authority of a user or application to perform actions. Confidentiality is the ability to encrypt data in order to prevent its access and integrity is the ability to detect data tampering. Non-repudiation is the ability to ensure that messages are sent and received by those that claim to have sent and received.

In order to maintain system-wide security and integrity, the above security principles and techniques shall be applied in such a way that if the security of a single SGUI interaction is compromised it does not affect the security of other SGUI interactions. Furthermore to ensure proper operations and accountability, the SGUI shall support means to audit and monitor interactions through the SGUI. This includes the ability to log transactions and exchange status information.

Consumer privacy shall also be considered, with interface design permitting minimal information transfer. Privacy protection uses some security tools such as encryption and authentication, but establishing security does not ensure the privacy of customer data. Customers should be informed of and should be in agreement with plans for collecting personally-identifiable data, uses of these data, the length of data retention, data anonymization, and data obliteration when the data are no longer needed [12].

Security is typically composed with an interoperation specification for a specific deployment; a single security profile does not address all possible implementations. In addition, security requirements and functionality generally evolve more quickly than interface specifications. Different parties involved in interactions require different choices for security, privacy, and reliability. Details of security requirements for particular interactions across the SGUI are too specific for inclusion in this technical report.

2.7.3 Scalability and performance

The SGUI needs to be designed to scale in multiple dimensions. It shall scale across different types of customers: residential, commercial, and industrial. It shall scale across a single customer, since a facility may have one or more SGUIs and a customer may have one or more facilities. It also shall scale across multiple customers, since a single service provider may interface to hundreds of thousands of separate SGUIs. A single SGUI may also connect to multiple grid-side service providers.

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The SGUI is a component in a large-scale, fast-responding energy system with wide geographical distribution. Business and economic requirements from business cases are often tied to the ability of service providers to reach large numbers of customers within rigid time constraints. Scalability can be characterized in terms of the quantity of actors involved and the performance required in terms of data throughput (i.e., messages per second) and data delays or latency (i.e., milliseconds). These may vary from thousands of large customers to millions of homes, and from hours-ahead DR signals to sub-second response times. The architecture chosen will determine the ability to meet application performance requirements. Technology that meets performance requirements in the context of relatively small numbers of actors may not meet performance requirements when a large number of actors are involved.

2.7.4 Maintainability

To ensure the continuing evolution of the customer centric applications on the Smart Grid, the SGUI design needs to ensure maintainability. It should be understood that the SGUI will evolve over time and methods should be included to ensure backwards compatibility and ability to evolve standards. The methods should also extend to identify, communicate and diagnose exceptions and errors at SGUI.

3 Country actions and perspective on Smart Grid user interface

3.1 General

Subclause 3.2 starts with member country perspectives on SGUI, followed (3.3) by a summary of use cases submitted by each country (with use cases details provided in Annex C), and then (3.4) an analysis of the use cases to derive common classes of use cases (e.g. communicating DR events, price signals, etc.). Subclause 3.5 calls out some specific issues that need attention, including use cases of member countries that do not fit well with the consensus SGUI perspective presented in Clause 2.

3.2 Overview of country experiences

3.2.1 China perspective

3.2.1.1 China’s research and practice in Smart Grid user domain

China has made great efforts in promoting energy savings and emissions reduction in the whole society, and has valued it as a part of accelerating the transformation of their economic development mode, with the vision to benefit the power grid enterprise, third parties such as service providers, and customers through the deployment of demand response, energy efficiency evaluation, renewable energy integration, and interactive services in the Smart Grid. A practical way to realize the vision is to make good use of business resources on the grid side, to fully explore the dispatchable loads on the user side, and to develop standards and specifications on the Smart Grid user domain. Standardization on information exchange between grid and user interface will promote the information exchange and business integration between the grid side and the user side, facilitate innovation on the business mode for Smart Grid, lower the R&D cost and implementation cost for the service provider and the manufacturer, enhance the safety and service of the grid enterprise, and satisfy the diversified requirements of customers, such as energy conservation and efficiency improvement.

Since China launched the Strong and Smart Grid Construction program in 2009, the State Grid Corporation of China (SGCC) has carried out significant research and practice in the customer domain. By the end of 2011, SGCC finished construction of EV charge/switch facilities covering 26 provinces, installed and applied 51,62 million smart meters, constructed 28 smart communities and buildings, provided energy management service for 35 000 households; finished the main station construction for the power consumption information collecting system in all provincial electric power companies, realized information collection, load management, auto-metering and billing service for 76,45 million households including industrial and residential customers. SGCC also achieved certain accomplishments in integration of roof solar and wind, pre-pay billing system, interactive service platform of smart

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power consumption, and other areas. In 2012, SGCC and Honeywell together launched a project to study the demonstration and feasibility of DR in Smart Grid. The project deployed auto–DR systems and devices in the district administration office, commercial buildings, office buildings and industrial users, which received significant effect in reducing peak load.

3.2.1.2 China's efforts on system construction of Smart Grid standards

In March 2009, SGCC launched the research project on Smart Grid standards system. A research team consisting of experts of various domains from China EPRI was assigned to this project. Through a year's effort, and considering comments and opinions from interested parties, and after several revisions, the team came up with the *SGCC Framework and Roadmap for Strong and Smart Grid Standards*, covering 8 domains, 26 technical areas and 92 standards series.

In order to boost China's Smart Grid construction, the Bureau of Energy of the National Development and Reform Commission (NDRC) and Standardization Administration of China (SAC) set up a working group on the national level to promote the standardization of the Smart Grid. Currently, the group is working on the draft of *Smart Grid Technical Standards System of China* with nationwide support of domain experts. In the customer domain of China's standards system, the following areas are given priority:

- Advanced metering infrastructure
- Demand response
- Customer energy management
- Power energy efficiency
- Electric vehicle charging
- Electric storage
- Distributed energy resource
- Electric energy management service (interactive service platform)

3.2.1.3 Latest developments of the Smart Grid standardization in China

According to the arrangement of the National Development and Reform Commission (NDRC) and the SAC, the following national standards are under development:

- Effect monitoring and comprehensive evaluation of demand response
- General specification of electric power efficiency assessment
- Metering and certification specification of power conservation through demand response
- Guidelines for energy efficiency evaluation in low-mid voltage distribution grids
- Series standards of public service platform for user side management
- Series standards of electric energy efficiency monitoring system
- Technical standards of aggregating and acquisition device for energy efficiency

3.2.2 U.S. perspective

The United States (U.S.) has made significant advancements on developing a standards infrastructure to enable a future Smart Grid. The U.S effort is led by the National Institute of Standards and Technology (www.nist.gov/smartgrid). NIST is mandated by U.S. law (the Energy Independence and Security Act of 2007) to assume primary responsibility for coordinating the development of a standards framework to achieve interoperability of Smart Grid devices and systems. The U.S. plan for Smart Grids is described in the *NIST Framework and Roadmap for Smart Grid Interoperability Standards Release 2.0*:

http://www.nist.gov/smartgrid/upload/NIST_Framework_Release_2-0_corr.pdf.

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To carry out its mandate, NIST established a public-private partnership called the Smart Grid Interoperability Panel (SGIP). The SGIP engages national and international stakeholders from the entire Smart Grid community in a participatory process to identify applicable standards, gaps in currently available standards, and priorities for new standardization activities for the evolving Smart Grid. The SGIP has over 700 member organizations representing 22 interest categories. Over 100 of the member organizations are from outside the U.S. The work of the SGIP has already had significant impact resulting in several new or revised U.S. and international standards.

SGIP is focusing on standards in the following areas to encourage interoperability among the components of smart grids:

- Demand response and consumer energy efficiency
- Wide area situational awareness
- Electric storage
- Electric transportation
- Advanced metering infrastructure
- Distribution grid management
- Network communications
- Cyber security

Specific standard gaps are identified and addressed in the SGIP process through the creation of priority action plans (PAPs). A PAP is both documentation of a specific need with targeted deliverables and a collection of experts from the SGIP community who work to produce the deliverables. A PAP typically develops use cases and other preliminary work that is offered to a standards development organization to accelerate their standards development process. The PAP monitors the development of the standard and evaluates how well the resulting standard meets the identified industry need. Several PAPs and their associated standards have scopes that are relevant to PC 118.

Figure 6 shows a conceptual Smart Grid architecture model based on the seven domains defined in the NIST Framework. This architectural model was used to help identify existing national and international standards that are critical to achieving a Smart Grid and to identify gaps that need to be filled in order to achieve interoperability of products and systems. We believe that standards related to a “Smart Grid user interface” are most strongly associated with the interface points in Figure 6 where the solid black lines connect to the Customer domain (lower right).

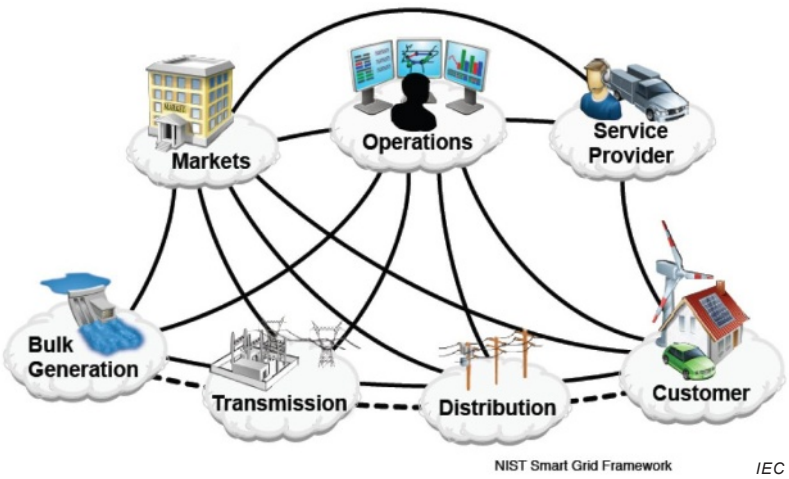

Figure 6 – NIST smart grid conceptual model (from NIST Framework 2.0)

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3.2.3 European perspective

The Smart Grid standardization framework in Europe is pushed by two mandates of the EU: Smart Metering M441, and Smart Grid M490. The answer to these standardization mandates is jointly worked by CEN, CENELEC and ETSI. The standardization in the field of the so called “Home and Building Electronic System” (HBES) is handled by CENELEC (CLC) TC 205. For the Smart Grid related items CLC established a special working group – CLC TC 205 WG 18. IEC TC 57 WG 21 defines the data models and communication services delivered to residences as well as commercial and industrial facilities. In ETSI, the M2M Technical Committee has specified an M2M generic architecture and APIs to enable vertical applications such as smart metering or smart grid use cases to access capabilities commonly needed (security, access rights, device management, store and forward, etc.). These specifications (ETSI TS 102690 and TS 102921) were published at the end of 2013.

For the handling of Smart Grid and smart metering in Europe, a reference architecture was defined (see Clause B.2). The management of loads, e.g. switching on or off, in a building (or residence) can be controlled by the grid (in dependence of the electricity generation). For the execution of the management of loads in a building a home and building electronic system (HBES) is necessary. The HBES interacts with the Smart Grid architecture via the addition of a utility customer energy manager (CEM) interacting with the HBES via a Smart Grid energy management gateway. To enable the Smart Grid functions in the building the energy management gateway and the CEM play a key role. To assure the interworking of devices from different manufactures all units shall work on a standardized basis.

The resulting standardization structure has these standards bodies with the following responsibilities: TC 57 WG 21 for the grid side of the SG user interface, TC 205 for the SG connection to the HBES and TC 59 WG 7 for customer devices like washing machines, refrigerators, and so on.

In order to enable differentiation between various vendors of customer energy managers, its behaviour will not be standardized, but the framework and the data structures for the interface will be standardized. If interoperability and the independence of the customer energy manager are a requirement, then a customer energy manager framework (CEMF) is needed. The task of CENELEC TC 205 WG 18 is to describe this CEMF in a normative way. The result of this WG will be the EN 50491-12 standard. As in reality there is not only one type of HBES in the market it is necessary to define a solution that enables to have a unique standardization in the grid and at the CEM. The solution is one common framework with one neutral standardized interface for the connection (mapping) of any HBES.

The input of the framework is described in the IEC 62746 [13] series. The framework will be described in EN 50491-12 [14]. The mapping to the HBES / BACS is described in the specifications of the different systems (e.g. EN 50090 series). In detail the architecture of the gateway is as follows (see Figure 7):

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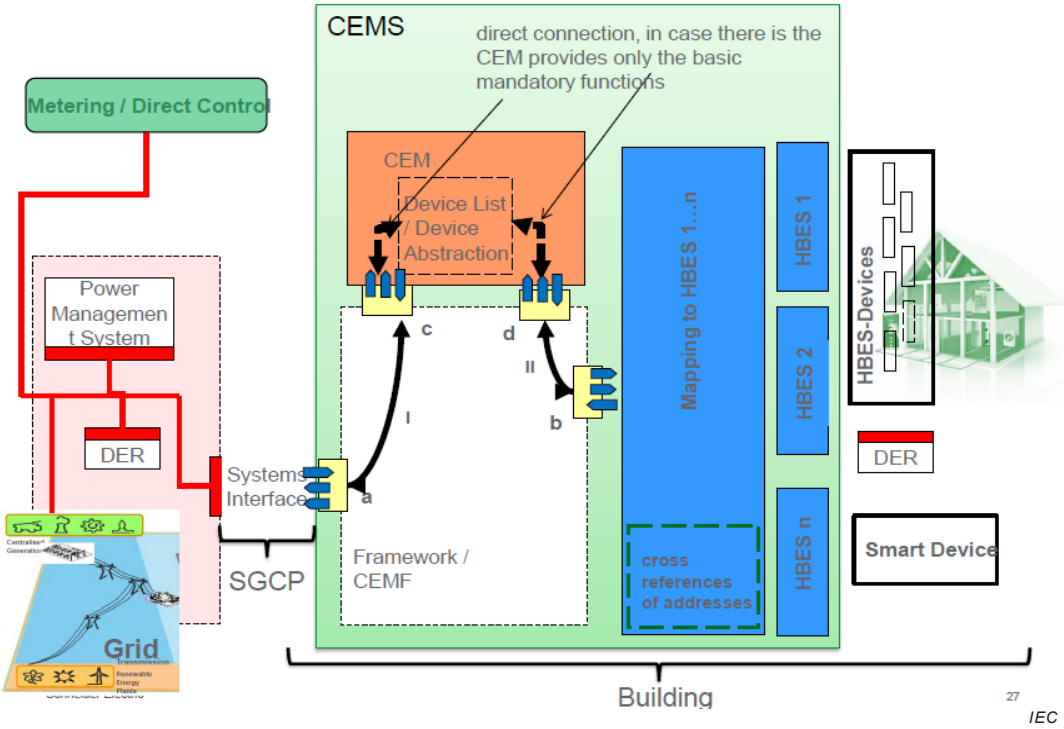

Figure 7 – Architectural details of the EN 50491-12 CEM framework

More details (with schematics of architecture) are presented in Clause B.2.

3.2.4 France perspective

France has already a long history and experience, recognized worldwide, in demand response, either through:

- Tariffs (supplier or utility): time of use, dynamic tariffs (critical peak pricing, fixed or variable, such as day/night tariffs or so-called “TEMPO” tariff).
- Incentive DR programs: direct load control and interruptible load (curtailment), proposed by utilities to cover internal needs, and potentially emergency programs.

France has launched Smart Grid initiatives at least in two major areas: the “Linky” smart metering program, and the “Smart Grid trials” program.

As a guideline framework to these initiatives (see details below), the Smart Grids standardization working group within the French Committee for the Strategic Orientation of Eco-Industries (COSEI) has especially formalized three high-level functional architectures, suitable for those programs (see Figure 8). Having been validated by the French Ministry of Industry (DGCIS), this work reflects a consensus among the stakeholders (French equipment manufacturers of the power sector, telecommunications operators and Électricité de France (EDF) Group) that are members of the Smart Grids standardization working group within the French Committee for the Strategic Orientation of Eco-Industries (COSEI). These three high-level functional architectures are located downstream of the electricity meter (smart home in the Smart Grid context). The scope focuses on electricity-related residential services and includes neither security nor health care services nor electric vehicles.

The architectures enable the management of electric flexibility within a smart home environment as well as the related customization and information services. The electric flexibility of a smart home is its ability to increase or decrease its electricity consumption in response to signals intended to change its load curve.

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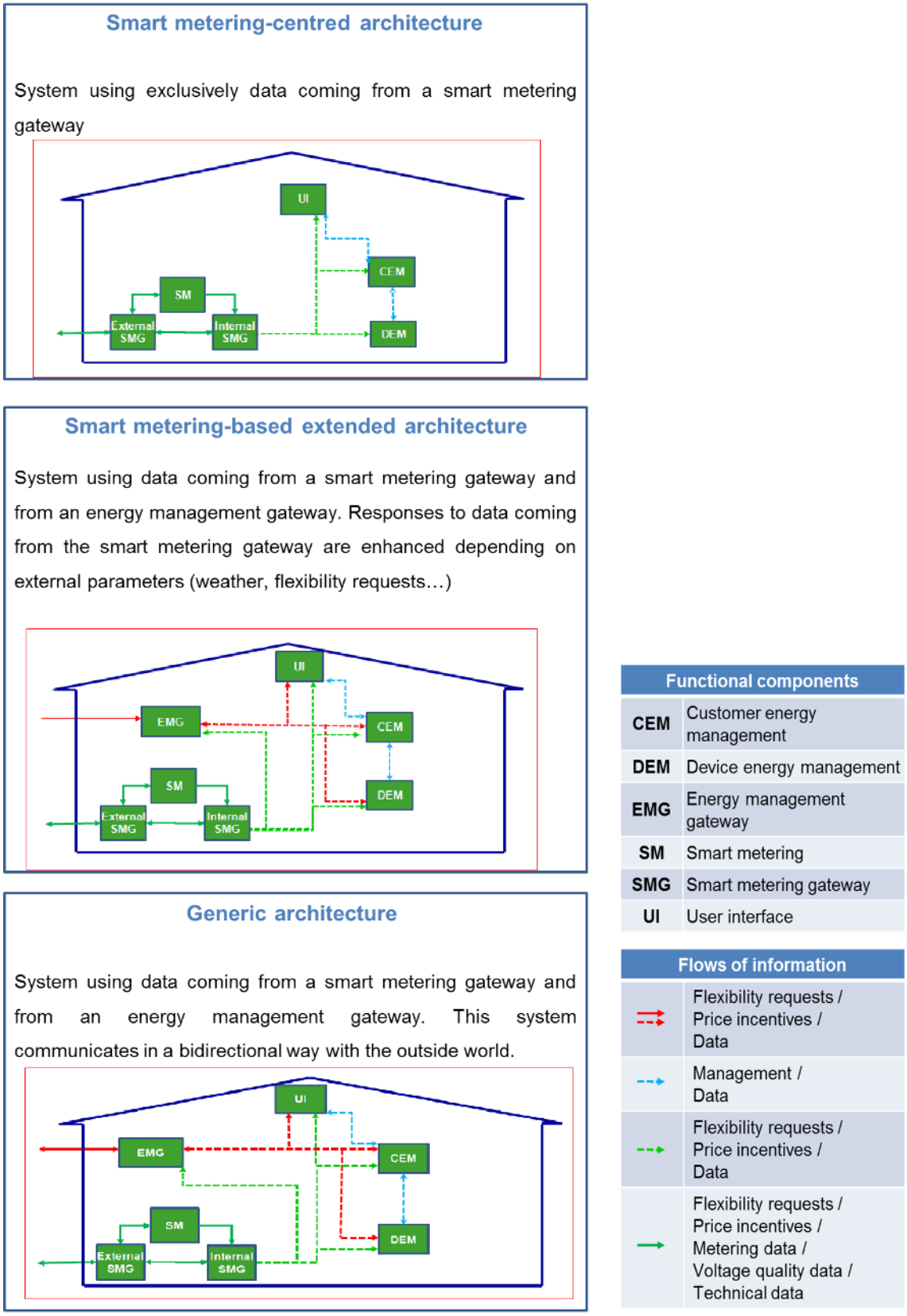

Figure 8 – Example COSEI architecture diagrams

In order to design these architectures, actor roles were identified, from which functional components of the smart home system were derived and the corresponding flows of exchanged information have been described through a use cases approach. These are shown

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in Figure 8. Indeed, a subset of the use cases that have been submitted to the IEC TC 8 WG 6 (called “Generic Smart Grid requirements”) is the following:

- Manage the electric flexibility of a smart home depending on price incentives received through the smart meter.
- Manage the electric flexibility of a smart home depending on flexibility requests received through the smart meter or a WAN-HAN interface.
- Manage exceptions to automatic responses related to price incentives or flexibility requests.
- Customize automatic responses related to price incentives or flexibility requests.
- Process information likely to impact the smart home behavior (mobile peak period notifications, weather forecast, consumption estimates, etc.).

The functional components are defined as:

- Smart metering (SM) – Combination of the following meter-related functions from the Smart Metering reference architecture:
  - Metrology functions including conventional meter display (register or index) that are under legal metrological control. When under metrological control, these functions shall meet the essential requirements of the MID (Measuring Instruments Directive – 2004/22/CE);
  - One or more additional functions not covered by the MID. These may also make use of the display.
- Internal smart metering gateway (Internal SMG) – Meter communication functions between the smart meter and the smart home.
- External smart metering gateway (External SMG) – Meter communication functions between the area of grid and the smart meter.
- Energy management gateway (EMG) – Borderline between the WAN and the HAN.
- Device energy management (DEM) – Function adapting the operations of a given electrical device depending on the incoming orders, resident customization and potential exceptions that may be manually done locally.
- Customer energy management (CEM) – Function enabling the definition of energy management strategies of one or several related DEM depending on metering data, price incentives, flexibility requests, additional information coming from other channels such as the Internet, resident customization and potential resident dispensations. This function includes a processing ability notably in order to take resident customization and electrical data enhancement into account.
- User interface (UI) – User interface for the resident or the client. The UI can be connected to the smart home HAN or to the WAN.

Table 1 presents the correspondence between some examples of hardware components that can be found in a smart home environment and their potential integrated functional components. It is not intended to be exhaustive.

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Table 1 – Correspondence between hardware components in smart homes and their potential integrated functional components

		Functional components						
		SM (Smart metering)	Internal SMG (Internal smart metering gateway)	External SMG (External smart metering gateway)	EMG (Energy mgmt gateway)	CEM (Customer energy mgmt)	DEM (Device energy mgmt)	UI (User interface)
Examples of hardware components	Smart meter	X	X	X				X
	Smart meter radio transmitter toward the smart home		X					X
	Interface between the HAN and the low-voltage grid			X				
	WAN-HAN interface				X			X
	Smart Home controller					X		X
	Appliances (connected home devices, that can receive orders; e.g., air conditioners, heaters,…)						X	X
	Smart appliances (connected home devices with embedded "intelligent" capabilities: clothes washer, heat pump, refrigerator)					X	X	X
	Display							X

The above generic architecture entirely reflects a consensus among the French stakeholders. In this architecture, as the system uses data coming from two sources, electric flexibility can be managed in a more complete way, covering more business cases.

Those reference architectures are suitable for the following programs:

a) "Linky" smart metering program

In conformance with the European directive, EDF has launched the Linky program in order to replace by 2020 the current metering system by an advanced metering infrastructure, potentially including 35 million meters.

As a first step, a trial comprising the deployment of 300 000 meters was done in 2012 in the areas of Lyon and Tours. After one year, the feedback and learnings are successful. The French government has validated the launch of the first step of the generalization. EDF Group launched in July 2013 a tender for the provision of 3 million of Linky smart meters that are to be deployed in 2015 and 2016.

This deployment of the Linky smart metering system will pave the way for the Smart Grids in France. In addition, the details for DR through smart meter infrastructure, including architecture diagrams, are presented in Clause B.3.

b) Smart grid trials program

The French Environment and Energy Management Agency, ADEME, has launched an important Smart Grid program through several calls for tenders for Smart Grid trials projects, co-founded by the partners of the projects and by the ADEME.

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These trials projects are focused on some or all of the five main Smart Grid targets:

- integration of renewable energy, at the grid level and/or at the end customer location;
- integration of energy storage (thermal, battery, other) at the grid level and/or at the end customer location;
- demand response (generator/storage/load – tariff & direct control);
- network management and control;
- energy services (information to customers, control of equipment to optimize the response, etc.).

In addition, the integration of electrical vehicles was also considered in a new trial project launched in 2013.

These targets are closely bound to each other, and the demand response or demand side management may be considered as central and embedded in almost all the projects.

As an example, the three following projects can be seen as the most remarkable projects:

- Smart Electric Lyon, in the area of Lyon, is targeting smart grid compliant equipment in the home that is able to adapt to the demand response signals sent through the Linky smart metering infrastructure, with trials in 25 000 households.
- Nice Grid, in the area of Nice, is targeting grid stability with a high level of integration of renewables (photovoltaic systems), energy storage, on the grid or in the homes, and demand response at the customer level. Nice Grid is one of the six demonstrations of the European GRID4EU project, the Large-Scale Demonstration of Advanced Smart Grid Solutions with wide Replication and Scalability Potential for Europe.
- Millener: in the context of isolated electric grids, with non-existent or small interconnections such as insular systems, the project, dedicated in the residential sector, aims at better integrating massive penetration of dispersed solar home systems through demand response and individual battery storage. It also tests energy saving solutions (information to customer).

3.2.5 Korea perspective

In order to establish Smart Grid infrastructure, Korea introduced the “Intelligent Power Grid Development and Distribution Promotion Act” in 2011. On the basis of this Act, standardization activities have been implemented mainly by the Korean Agency for Technology and Standards (KATS), and the Korea Smart Grid Association (KSGA), which are the governmental and private organizations, respectively.

KATS has designed the strategic policy of Smart Grid standardization, and the framework and roadmap of the Smart Grid interoperability, etc. Further, a coordinator appointed by KATS has the role to coordinate various related sectors and to support standard-related R&D and business. KSGA is involved in the standardization activities through the Smart Grid Standardization Forum, consisting of about 500 experts.

The framework and roadmap (see Table 2), the basis of Korean Smart Grid standardization, specify 9 domains (generation, transmission, distribution, marketing, operation, service provider, distributed resource, consumer, transportation), as well as selecting 50 developing items and 27 prioritized items out of 6 application services (AMI, DR, EV, wide area situational awareness (WASA), distributed energy resource/energy storage DER/ES, distribution grid management (DGM)). Further, a detailed standardization plan is scheduled to be added and the framework to be updated, reflecting the outcome of operating the test-bed and the implementation of the business plan.

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With regard to the smart grid user interface, Korea is conducting various tests, including the Jeju Smart Grid test bed, intelligent DR, etc., the results of which are taken into account in designing the framework and application services.

Table 2 – Korean framework domains and relation to SGUI

Top 3 domains	9 domains	Application services	Relation to SGUI
Smart power grid	Generation	1. Advanced metering infrastructure 2. Demand response 3. Electric vehicles 4. Wide area system monitoring and situation awareness 5. Distributed energy resource /energy storage 6. Distribution grid management	1. High level 2. High level 3. High level 4. Low level 5. High level 6. Middle level
	Transmission		
	Distribution		
Smart service	Market		
	Operation		
	Service provider		
Smart prosumer	Distributed energy resource		
	Customer		
	Transportation		

NOTE 1 Pilot programs related to SGUI conducted in the Jeju Smart Grid test-bed include tests to optimize the power consumption of residence and commercial buildings, and to run the business model of selling power generated and stored by the consumer to the power company. Additionally, tests cover controlling electrical appliances by applying the Smart Energy Profile (SEP) transferred by the Energy Service Provider

NOTE 2 An intelligent DR program is operated in trial with a view to maintaining the reliability of the power system applied with OpenADR 1.0 in the structure of DRAS (demand response automation server)/client.

3.2.6 Japan perspective

In four demonstration tests from 2010 to 2014 (Table 3), utilities employed smart meters to test the effectiveness of seasonal and time-specific rates. In addition to TOU and CPP rates, which factor in price elasticity, they also tested rebates, including PTR (peak time rebates) and CBP (critical bottom pricing). The Kitakyushu demonstration test features, real-time pricing—a system where electricity prices change based on increases or decreases in demand each day. The test began in April 2012.

Table 3 – Four regional demonstration tests in Japan

Region	Overview
Yokohama City	Tokyo Electric Power et al. plan to begin testing demand response in the spring of 2013, with the ultimate goal of expanding targeted households to 4 000 homes. It plans to use data from the test in its evaluations of dynamic pricing and other flexible pricing options for its service area.
Toyota City	Toyota and Chubu Electric Power have been testing demand response since December 2011.
Keihanna District	Beginning in the summer of 2012, Kansai Electric Power et al. will be testing demand response in 900 households.
Kitakyushu City	In April 2012, the City of Kitakyushu, Nippon Steel et al. plan to test a “real time pricing” system, which changes electricity prices on any given day in response to supply and demand. This test, the first such attempt in the world, will involve 230 households and 50 factories and other industrial establishments. The findings from this test will be provided to Kyushu Electric Power.

3.2.7 India perspective

In August 2013, the Ministry of Power, Government of India, released the “Smart Grid Vision and Roadmap for India”. The road map covers the 12th, 13th and 14th 5-year plan periods from 2012 to 2027, and outlines a series of time-framed, target-driven measures, across

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different areas for development of the Smart Grid model for India. This document was created by the participation and collaboration of member organizations of the India Smart Grid Forum and the India Smart Grid Task Force.

In line with the roadmap, a set of 14 pilot projects have been initiated in India. The functional areas that will be demonstrated in these projects are listed as follows, with the number indicating the number of pilot projects in which that function is addressed.

a) Advance metering infrastructure, residential – 9
b) Advance metering infrastructure industrial – 13
c) Peak load management (PLM) – 10
d) Demand response (DR) – 10
e) Outage management (OM) – 7
f) Power quality (PQ) – 4
g) Distributed generation (DG) – 2
h) Micro grids (MG) – 1

It can be noted that in most of the pilot projects advanced metering infrastructure, peak load management, and demand response play an important role. These areas also come under the Smart Grid user interface between the grid side operators and the customer side operators. Hence, standardization of the Smart Grid user interface is of particular interest for India.

NOTE Link to India Smart Grid Vision and Roadmap:
http://indiasmartgrid.org/en/Lists/News/Attachments/154/India Smart Grid Forum Booklet.pdf

3.3 Use cases from PC 118 member countries

3.3.1 General

Subclause 3.3 presents an introduction to the use cases contributed by member countries. Member countries were asked to provide use cases each country believed relevant to the SGUI. More details on these use cases may be found in Annex C.

3.3.2 China use cases

Table 4 – China use case classification and use case summary

Use case	Name of use case category	Short description
CN01	Generic	Common and basic UC
CN02	Demand response (DR)	DR related UC
CN03	Energy efficiency (EE)	Evaluation of EE related UC
CN04	Distributed energy resource (DER)	DER management related UC
CN05	Electric vehicle charging (EVC)	EV charging related UC
CN06	Load management(LM)	LM related UC

Detailed descriptions for the Chinese use cases (Table 4) are given in Clause C.2.

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