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**DEFINITION, EXPECTED SERVICES, FUNCTIONALITIES
AND BENEFITS OF SMART GRIDS**

Accompanying documents to

**COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN
PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL
COMMITTEE AND THE COMMITTEE OF THE REGIONS**

Smart Grids: from innovation to deployment

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¹ This Annex contains selected texts from the deliverables of the European Task Force for Smart Grids to provide detailed descriptions and explanations about the definition, services, functionalities and benefits of Smart Grids. For more information, see reports from Expert Group 1 and 3:
http://ec.europa.eu/energy/gas_electricity/smartgrids/taskforce_en.htm

1. SMART GRIDS CONCEPT AND DEFINITIONS

A Smart Grid is an electricity network that can cost efficiently integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety.

Though elements of smartness also exist in many parts of existing grids, the difference between a today's grid and a smart grid of the future is mainly the grid's capability to handle more complexity than today in an efficient and effective way. A Smart Grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies in order to:

- Better facilitate the connection and operation of generators of all sizes and technologies.
- Allow consumers to play a part in optimising the operation of the system.
- Provide consumers with greater information and options for how they use their supply.
- Significantly reduce the environmental impact of the whole electricity supply system.
- Maintain or even improve the existing high levels of system reliability, quality and security of supply.
- Maintain and improve the existing services efficiently.
- Foster market integration towards European integrated market.

The implementation of this concept will be made possible by the participation of all Smart Grid's actors, according to their specific roles and responsibilities which are described in greater detail in the report of the Expert Group 3 of the Task Force Smart Grids. Accordingly, smart grid participants are categorised as follows:

- Network operators: transmission and distribution system/network operators (TSOs and DSOs/DNOs).
- Grid users: generators, consumers (including mobile consumers), storage owners.
- Other actors: suppliers, metering operators², ESCOs, aggregators, applications and services providers, power exchange platform operators.

In most EU Member States, DSOs combine several roles, including network operators, metering operators (including data collection) and application and services providers (data clearing).

The public consultation process started by ERGEG identified network operators (DSOs and TSOs) as the prime movers for the deployment of Smart Grids. Their task is to implement the network infrastructure that has a central role which allows the flow of both energy and information between consumers, generators, suppliers and all the other actors in the new smart grid framework. As well, respondents to the consultation agreed that DSOs (and TSOs), as prime movers for the deployment of smart grids, will allow new marketplaces and opportunities for suppliers and energy service companies.

Conceptually, some Smart Grid participants provide services, based on a combination of functionalities, to other Smart Grid participants.

² Depending on the national market model, the metering operators may be distribution companies, suppliers or meter companies.

A Smart Grid service identifies, and can be commonly considered as, the outcome a user needs/will need from the electricity grid in a fully developed liberalised market; it is associated to one provider and to a number of primary beneficiaries, recognising that the benefits will ultimately be reflected in consumer societal and environmental terms.

The achievement of service outcomes is possible only through Smart Grids functionalities, which represent elementary bricks through which services can be implemented and delivered to beneficiaries. While some Smart Grid's services are identified at this stage it is expected that new functionalities will be developed and may be deployed over time. The Smart Grid's infrastructure shall provide enough flexibility for new functionalities to be deployed.

2. HIGH LEVEL SERVICES OF SMART DISTRIBUTION GRIDS

Smart Grid services in the liberalised market

The detailed services to be provided in Smart Grid solutions will have to be agreed in discussion between the relevant parties. However the following represents a list of the broad services envisaged, showing the provider of the service and the primary beneficiaries.

A provider of a service is a participant that is responsible for such a service alone or in combination with other participants. Primary beneficiaries are participants that require or directly benefit from the services, recognising that the full benefits from these services are shared among a much wider group of participants.

High-level services

A. Enabling the network to integrate users with new requirements

Outcome: Guarantee the integration of distributed energy resources (both large and small-scale stochastic renewable generation, heat pumps, electric vehicles and storage) connected to the distribution network.

Provider: DSOs

Primary beneficiaries: Generators, consumers (including mobile consumers), storage owners.

B. Enhancing efficiency in day-to-day grid operation

Outcome: Optimise the operation of distribution assets and improve the efficiency of the network through enhanced automation, monitoring, protection and real time operation. Faster fault identification/resolution will help improve continuity of supply levels.

Better understanding and management of technical and non-technical losses, and optimised asset maintenance activities based on detailed operational information.

Provider: DSOs, metering operators

Primary beneficiaries: Consumers, generators, suppliers, DSOs.

C. Ensuring network security, system control and quality of supply

Outcome: Foster system security through an intelligent and more effective control of distributed energy resources, ancillary back-up reserves and other ancillary services. Maximise the capability of the network to manage intermittent generation, without adversely affecting quality of supply parameters.

Provider: DSOs, aggregators, suppliers.

Primary beneficiaries: Generators, consumers, aggregators, DSOs, TSOs.

D. Enabling better planning of future network investment

Outcome: Collection and use of data to enable more accurate modelling of networks especially at LV level, also taking into account new grid users, in order to optimise infrastructure requirements and so reduce their environmental impact. Introduction of new methodologies for more 'active' distribution, exploiting active and reactive control capabilities of distributed energy resources.

Provider: DSOs, metering operators.

Primary beneficiaries: Consumers, generators, storage owners.

E. Improving market functioning and customer service

Outcome: Increase the performance and reliability of current market processes through improved data and data flows between market participants, and so enhance customer experience.

Provider: Suppliers (with applications and services providers), power exchange platform providers, DSOs, metering operators.

Primary beneficiaries: Consumers, suppliers, applications and services providers.

F. Enabling and encouraging stronger and more direct involvement of consumers in their energy usage and management

Outcome: Foster greater consumption awareness taking advantage of smart metering systems and improved customer information, in order to allow consumers to modify their behaviour according to price and load signals and related information.

Promote the active participation of all actors to the electricity market, through demand response programmes and a more effective management of the variable and non-programmable generation. Obtain the consequent system benefits: peak reduction, reduced network investments, ability to integrate more intermittent generation.

Provider: Suppliers (with metering operators and DSOs), ESCOs.

Primary beneficiaries: Consumers, generators. Indeed, consumers will benefit:

- either because these services will contribute to the 20/20/20 targets
- or directly through improvement of quality of supply and other services

The hypothesis made here is that company efficiency and the benefit of the competitive market will be passed to consumers– at least partly - in the form of tariff or price optimisation, and is dependent on effective regulation and markets.

3. FUNCTIONALITIES OF SMART DISTRIBUTION GRIDS

As described in chapter 3, the delivery of Smart Grid services requires specific network functionalities. This chapter lists a series of functionalities grouped according to the high-level services identified in chapter 6. In some cases these functionalities could be broken down further into smaller sub-functionalities. However it is preferred to adopt this level of detail in order to:

- specify a limited number of items; and
- avoid the imposition of any specific market model with respect to other options, as a very detailed list could inhibit some business possibilities.

A. Enabling the network to integrate users with new requirements

1. Facilitate connections at all voltages/locations³ for all existing and future devices with Smart Grid solutions through the availability of technical data and additional grid information to:
 - simplify and reduce the cost of the connection process subject to maintaining network integrity/safety;
 - facilitate an ‘open platform’ approach – close to ‘plug & play’;
 - make connection options transparent;
 - facilitate connection of new load types, particularly EV;
 - ensure that the most efficient DER connection strategies can be pursued from a total system perspective;
2. Better use of the grid for users at all voltages/locations, including in particular renewable generators.
3. Registers of the technical capabilities⁴ of connected users/devices with an improved network control system, to be used for network purposes (ancillary services).
4. Updated performance data on continuity of supply and voltage quality to inform connected users and prospective users.

B. Enhancing efficiency in day-to-day grid operation

5. Improved automated fault identification and optimal grid reconfiguration after faults reducing outage times:
 - using dynamic protection and automation schemes with additional information where distributed generation is present;
 - strengthening Distribution Management Systems of distribution grids.
6. Enhanced monitoring and control of power flows and voltages.
7. Enhanced monitoring and observability of network components down to low voltage levels, potentially using the smart metering infrastructure.
8. Improved monitoring of network assets in order to enhance efficiency in day-to-day network operation and maintenance (proactive, condition based, operation history based maintenance).

³ Technical constraints permitting and according to the price signal.

⁴ Network users/devices, in order to actively participate/be managed in network’s operations and energy management, must be characterised by adequate technical capabilities. Considering the active control and demand-response of Distributed Energy Resources (i.e. generators, controllable loads and storage) some of the most relevant technical capabilities that have to be taken into account are:

- Active – reactive power capabilities.
- Dynamic response.
- Electric storage capacity in terms of energy and power.

For example, referring to the renewable generators participation in the network voltage regulation or power flows control, the generator reactive power capability curve and the other capabilities aforementioned, are technical constraints that have to be managed.

9. Identification of technical and non technical losses through power flow analysis, network balances calculation and smart metering information.
10. Frequent information on actual active/reactive injections/withdrawals by generation and flexible consumption to system operator.

C. Ensuring network security, system control and quality of supply

11. Solutions to allow grid users and aggregators to participate in an ancillary services market to enhance network operation.
12. Improved operation schemes for voltage/current control taking into account ancillary services.
13. Solutions to allow intermittent generation sources to contribute to system security through automation and control.
14. System security assessment and management of remedies, including actions against terrorist attacks, cyber threats, actions during emergencies, exceptional weather events and force majeure events.
15. Improved monitoring of safety particularly in public areas during network operations⁵.
16. Solutions for demand response for system security purposes in required response times.

D. Better planning of future network investment

17. Better models of DG, storage, flexible loads (including EV), and the ancillary services provided by them for an improvement of infrastructure planning.
18. Improved asset management and replacement strategies by information on actual/forecasted network utilization.
19. Additional information on supply quality and consumption made available by smart metering infrastructure to support network investment planning.

E. Improving market functioning and customer service

20. Solutions for participation of all connected generators in the electricity market.
21. Solutions for participation of VPPs in the electricity market, including access to the register of technical capabilities of connected users/devices.
22. Solutions for consumer participation in the electricity market, allowing market participants to offer:
 - time of use energy pricing, dynamic energy pricing and critical peak pricing;
 - demand response / load control programmes;
23. Grid solutions for EV recharging:
 - open platform grid infrastructure for EV recharge purposes accessible to all market players and customers.
 - smart control of the recharging process through load management functionalities of EV.
24. Improved industry systems for settlement, system balance, scheduling and forecasting and customer switching.
25. Grid support to intelligent home/facilities automation and smart devices by consumers.
26. Individual advance notice to grids users for planned interruptions.
27. Customer level reporting in event of interruptions (during, and after event).

⁵ e.g.: control of access to the equipment, detection of fault on overhead networks, protection of the contents of the buildings.

F. Enabling and encouraging stronger and more direct involvement of consumers in their energy usage and management

28. Sufficient frequency of meter readings, measurement granularity for consumption /injection metering data (e.g. interval metering, active and reactive power, etc).
29. Remote management of meters.
30. Consumption/injection data and price signals via the meter, via a portal or other ways including home displays, as best suited to consumers and generators.
31. Improved provision of energy usage information, including levels of green energy available at relevant time intervals and supply contract carbon footprint.
32. Improved information on energy sources.
33. Individual continuity of supply and voltage quality indicators via meter, via portal or other ways including home displays.

Benefit	Potential key performance indicators ⁶
(1) Increased sustainability	Quantified reduction of carbon emissions Environmental impact of electricity grid infrastructure Quantified reduction of accidents and risk associated to generation technologies (during mining, production, installations, etc.)
(2) Adequate capacity of transmission and distribution grids for “collecting” and bringing electricity to the consumers	Hosting capacity for distributed energy resources in distribution grids Allowable maximum injection of power without congestion risks in transmission networks Energy not withdrawn from renewable sources due to congestion and/or security risks An optimized use of capital and assets
(3) Adequate grid connection and access for all kind of grid users	Benefit (3) could be partly assessed by: - first connection charges for generators, consumers and those that do both - grid tariffs for generators, consumers and those that do both - methods adopted to calculate charges and tariffs - time to connect a new user - optimization of new equipment design resulting in best cost/benefit - faster speed of successful innovation against clear standards
(4) Satisfactory levels of security and quality of supply	Ratio of reliably available generation capacity and peak demand Share of electrical energy produced by renewable sources Measured satisfaction of grid users with the “grid” services they receive Power system stability Duration and frequency of interruptions per customer Voltage quality performance of electricity grids (e.g. voltage dips, voltage and frequency deviations)
(5) Enhanced efficiency and better service in electricity supply and grid operation	Level of losses in transmission and in distribution networks (absolute or percentage) ⁷ . Storage induces losses too, but also active flow control increases losses. Ratio between minimum and maximum electricity demand within a defined time period (e.g. one day, one week) ⁸ Percentage utilisation (i.e. average loading) of electricity grid elements Demand side participation in electricity markets and in energy efficiency measures Availability of network components (related to planned and unplanned maintenance) and its impact on network performances Actual availability of network capacity with respect to its standard value (e.g. net transfer capacity in transmission grids, DER hosting capacity in distribution grids)
(6) Effective support of transnational electricity markets by load-flow control to alleviate loop-flows and increased interconnection capacities	Ratio between interconnection capacity of one country/region and its electricity demand Exploitation of interconnection capacities (ratio between mono-directional energy transfers and net transfer capacity), particularly related to maximisation of capacities according to the Regulation of electricity cross-border exchanges and the congestion management guidelines Congestion rents across interconnections
(7) Coordinated grid development through common European, regional and local grid planning to optimize transmission grid infrastructure	Benefit (7) could be partly assessed by: - impact of congestion on outcomes and prices of national/regional markets - societal benefit/cost ratio of a proposed infrastructure investment - overall welfare increase, i.e. running always the cheapest generators to supply the actual demand) → this is also an indicator for the benefit (6) above - Time for licensing/authorisation of a new electricity transmission infrastructure. - Time for construction (i.e. after authorisation) of a new electricity transmission infrastructure.
(8) Enhanced consumer awareness and participation in the market by new players	- Demand side participation in electricity markets and in energy efficiency measures - Percentage of consumers on (opt-in) time-of-use / critical peak / real time dynamic pricing - Measured modifications of electricity consumption patterns after new (opt-in) pricing schemes.

⁶ Some of these indicators are already used today in different EU Member States.

⁷ In case of comparison, the level of losses should be corrected by structural parameters (e.g. by the presence of distributed generation in distribution grids and its production pattern). Moreover a possibly conflicting character of e.g. aiming at higher network elements’ utilization (loading) vs. higher losses, should be considered accordingly.

⁸ In case of comparison, a structural difference in the indicator should be taken into account due e.g. to electrical heating and weather conditions, shares of industrial and domestic loads.

Benefit	Potential key performance indicators ⁶
	<ul style="list-style-type: none"> - Percentage of users available to behave as interruptible load. - Percentage of load demand participating in market-like schemes for demand flexibility. - Percentage participation of users connected to lower voltage levels to ancillary services
(9) Enable consumers to make informed decisions related to their energy to meet the EU Energy Efficiency targets	<ul style="list-style-type: none"> - Base to peak load ratio - Relation between power demand and market price for electricity - Consumers can comprehend their actual energy consumption and receive, understand and act on free information they need / ask for - Consumers are able to access their historic energy consumption information for free in a format that enables them to make like for like comparisons with deals available on the market. - Ability to participate in relevant energy market to purchase and/or sell electricity - Coherent link is established between the energy prices and consumer behaviour
(10) Create a market mechanism for new energy services such as energy efficiency or energy consulting for customers	<ul style="list-style-type: none"> - 'Simple' and/or automated changes to consumers' energy consumption in reply to demand/response signals, are enabled - Data ownership is clearly defined and data processes in place to allow for service providers to be active with customer consent - Physical grid related data are available in an accessible form - Transparency of physical connection authorisation, requirements and charges - Effective consumer complaint handling and redress. This includes clear lines of responsibility should things go wrong
(11) Consumer bills are either reduced or upward pressure on them is mitigated	<ul style="list-style-type: none"> - Transparent, robust processes to assess whether the benefits of implementation exceed the costs in each area where roll-out is considered are in place, and a commitment to act on the findings is ensured by all involved parties - Regulatory mechanisms exist, that ensure that these benefits are appropriately reflected in consumer bills and do not simply result in windfall profits for the industry - New smart tariffs (energy prices) deliver tangible benefits to consumers or society in a progressive way - Market design is compatible with the way the consumers use the grid