Smart Energy and Smart Grids

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References

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[2] Smart Grid Coordination Group, "Smart Grid Reference Architecture". november 2012. [Online]. Available at: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjDxbvZ7_32AhWrxIsKHR1zAi8QFnoECAcQAQ&url=https%3A%2F%2Fec.europa.eu%2Fenergy%2Fsites%2Fener%2Ffiles%2Fdocuments%2Fxpert_group1_reference_architecture.pdf&usg=AOvVaw3ucjTGByukhKna2_a75-6g

1 Smart grids

The smart grid is significantly broader term than smart metering. Smart metering is just a basic functionality within the smart grid, which aims to provide to all participants information about actual grid conditions and health and provide basic data for their decisions.

As true smart grid can be viewed a power grid, that can automatically reuse gathered information and provides services, that increase **reliability**, **survivability**, and **responsiveness** of the power grid.

Specifically, it can e.g., deal with locally produced energy, predict power outages before they occur, rapidly restore service. Such a grid can be called "self-healing" and "making decisions".

An aim is total automation of the electricity distribution network – including local production and consumption.

Some examples of automation are

a) Ability to automatically re-route electricity when a transmission line is downed

a) Reduce other flows when someone's rooftop solar panels suddenly send a burst of energy onto the grid.

Technically, the building blocks for a smart grid are already available. Deployment of smart grids is one of the priority thematic areas under the **Trans-European Networks for Energy** (*TEN-E*) policy (policy that is focused on linking the energy infrastructure of EU countries) aiming to help integrate renewable energy, complete the European energy market, and allow consumers to better regulate their energy consumption [1].

To achieve smart grid functionality, smart metering needs to be rolled out first. This step is taking place in many European countries, along with a movement from traditional electricity measurement to multi-energy metering.

The smart metering as the system can be viewed as one of the systems in the smart grid. The de-facto list of systems that are present in the smart grid provides [2] and is presented in the Tab. 1.

Tab. 1 Smart grid – list of the essential systems, note the Smart metering systems in the list

Domain or Function	**Systems**
Generation	Generation management system
Transmission management system	Substation automation system
	Blackout Prevention System - Wide Area Measurement Protection and Control System (WAMPAC)
	EMS SCADA system
	Flexible AC Transmission Systems
Distribution management systems	FACTS Substation automation system
	Feeder automation system
	Advanced Distribution Management System (ADMS)
	FACTS system
DER operation systems	DER operation system
Smart Metering systems	*AMI system*
	Metering-related back office system
Demand and production (generation) flexibility systems	Aggregated prosumers management system
Micro-grid	Micro-grid systems
Marketplace system	Marketplace system
	Trading system
E-mobility (connection to grid) Administration systems	E-mobility systems
Administration systems	Asset and Maintenance Management system
	Communication network management system

	Clock reference system
	Authentication, Authorization, Accounting system
	Device remote Management system
	Weather forecast and observation system

2 Smart grid architecture model (SGAM)

The important reference regarding smart grid systems and architecture of the smart grid as whole provides the **Smart Grid Architecture Model** (*SGAM*).

The original scope of the SGAM was created in the M/490 mandate of the **European Commission** (*EC*) to the European standardization bodies *CEN* (**Comité Européen de Normalisation**), *CENELEC* (**European Committee for Electrotechnical Standardization**), and *ETSI* (**European Telecommunications Standards Institute**).

The SGAM acts as a reference designation system providing three main axis for the dimensions: **Domains**, **Zones**, and **Interoperability Layers** as depicted on Fig. 1.

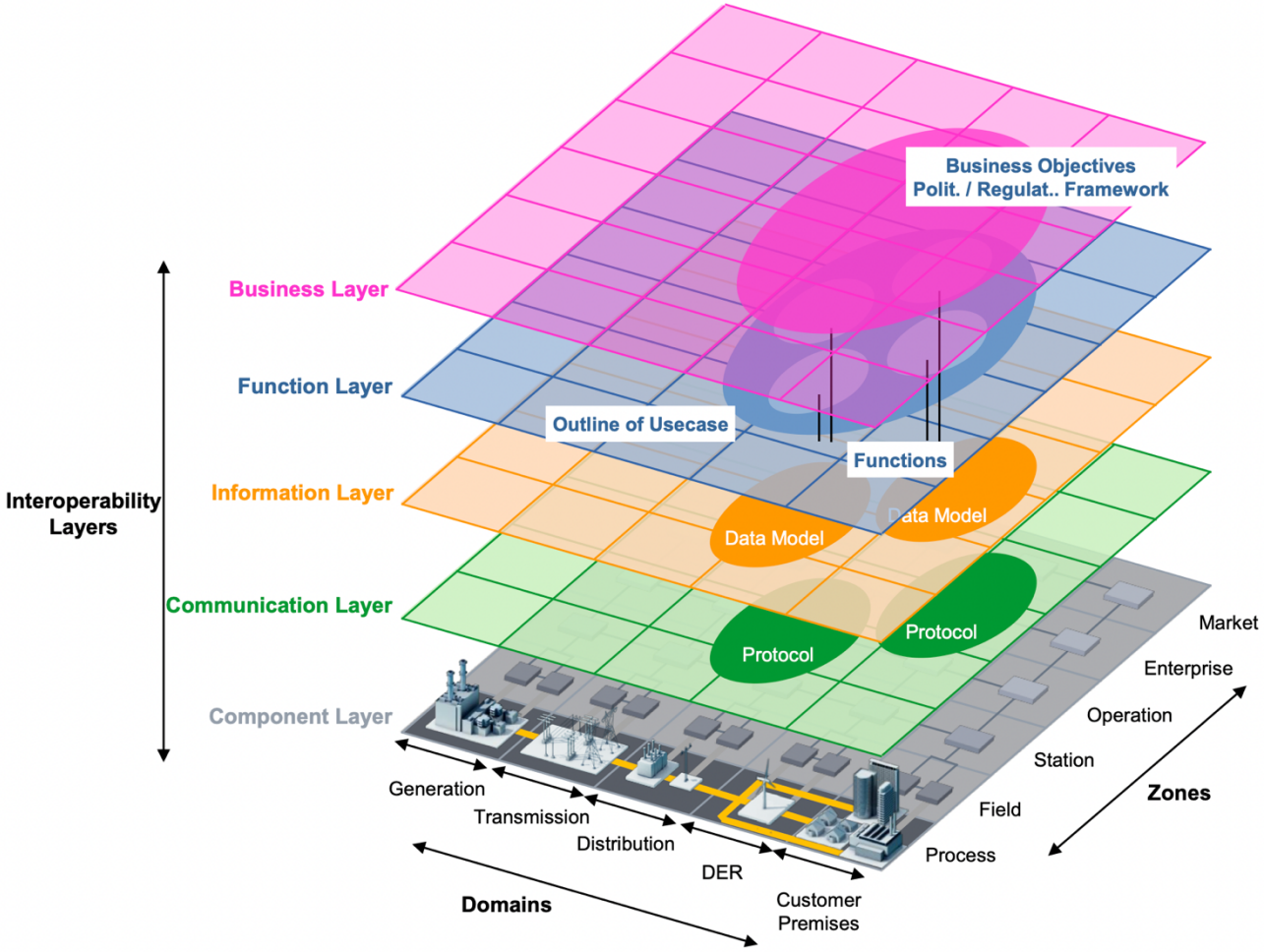

Fig. 1 Smart Grid Architecture Model framework [2]

As the key enabler of smart grid is seen the interoperability. The systems are considered as interoperable, if they are able to perform cooperatively a specific function by using information which is exchanged.

In SGAM there are defined 5 interoperability layers:

- **Business Layer** - Represents the business view on the information exchange related to smart grids. Can be used to map regulatory and economic (market) structures and policies, business models, processes, products and services.
- **Function Layer** - Describes functions and services including their relationships from an architectural viewpoint. The functions are represented independent from actors and physical implementations in applications, systems and components.
- **Information Layer** - Describes the information that is being used and exchanged between functions, services and components. It contains information objects and the underlying data models.
- **Communication Layer** - Describes protocols and mechanisms for the interoperable exchange of information between components
- **Component Layer** – Describes physical distribution of all participating components in the smart grid context.

The Domains basically represent the energy conversion chain similarly to the basic scheme of the electric grid as provided on Fig. 1, they can be described as follows:

- **Bulk Generation** - Represents generation of electrical energy in bulk quantities, such as by fossil, nuclear and hydro power plants, off-shore wind farms, large scale solar power plants, typically connected to the transmission system.
- **Transmission** - Represents the infrastructure and organization which transports electricity over long distances.
- **Distribution** - Represents the infrastructure and organization which distributes electricity to customers.
- **DER** - Represents distributed electrical resources directly connected to the public distribution grid, applying small-scale power generation technologies (typically in the range of 3 kW to 10.000 kW). These distributed electrical resources may be directly controlled by DSO.
- **Customer premises** – Reperesents both - end users of electricity, also producers of electricity. The premises include industrial, commercial and home facilities (e.g. chemical plants, airports, harbors, shopping centers, homes). Also represents the generation in form of e.g. photovoltaic generation, electric vehicles storage, batteries, micro turbines ...

The Zones are orthogonal to the domains and basically represent the Information and Communication Technology (ICT) based power system management, controlling the energy conversion chain. There are present two main concepts of aggregation:

- **Data aggregation** – Data from the field zone is usually aggregated or concentrated in the station zone to reduce the amount of data to be communicated and processed in the operation zone.
- **Spatial aggregation** – Aggregation from distinct locations to wider area (e.g. power system equipment is usually arranged in bays, several bays form a substation; multiple DER form a plant station, DER meters in customer premises are aggregated by concentrators for a neighborhood).

Based on this aggregation concepts an additional functional separation concept, the individual zones are described as follows [2]:

- **Process** - Includes the physical, chemical or spatial transformations of energy (electricity, solar, heat, water, wind ...) and the physical equipment directly involved. (e.g. generators, transformers, circuit breakers, cables).
- **Field** - Including equipment to protect, control and monitor the process of the power system, e.g. protection relays, bay controller, any kind of intelligent electronic devices which acquire and use process data from the power system.
- **Station** - Representing the areal aggregation level for field level, e.g. for data concentration, functional aggregation, substation automation, local SCADA systems, plant supervision...
- **Operation** - Hosting power system control operation in the respective domain, e.g. distribution management systems (*DMS*), energy management systems (*EMS*) in generation and transmission systems, microgrid management systems, virtual power plant management systems (aggregating several DER), electric vehicle (*EV*) fleet charging management systems.
- **Enterprise** - Includes commercial and organizational processes, services and infrastructures for enterprises (utilities, service providers, energy traders ...), e.g. asset management, logistics, work force management, customer relation management, billing.
- **Market** - Reflecting the market operations possible along the energy conversion chain, e.g. energy trading, mass market, retail market..

Against SGAM framework cube can be mapped all the systems that are used in smart grid (e.g. the essential systems provided in Tab. 1).