

Smart Energy and Smart Grids

Radoslav Vargic, Juraj Londák

References

- [1] 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%2Fexpert_group1_reference_architecture.pdf&usg=AOvVaw3ucjTGByukhKna2_a75-6g
- [2] F. Gao, R. Kang, J. Cao, a T. Yang, “Primary and secondary control in DC microgrids: a review”, J. Mod. Power Syst. Clean Energy, roč. 7, č. 2, s. 227–242, mar. 2019, doi: 10.1007/s40565-018-0466-5.

1 Microgrid as a system in smart-grid, main roles of smart-grid

Among the smart grid systems the **micro-grid systems** are a specialty.

From a “domain” dimension prospective, micro-grids are “Smart Grids in small” and cover 3 main domains: Distribution, DER and Customer premises as it is shown on conceptual diagram Fig. 1.

Micro grids essentially contain the same systems from these domains as the smart grids. The rest of smart grid is sometimes called as **macro-grid**.

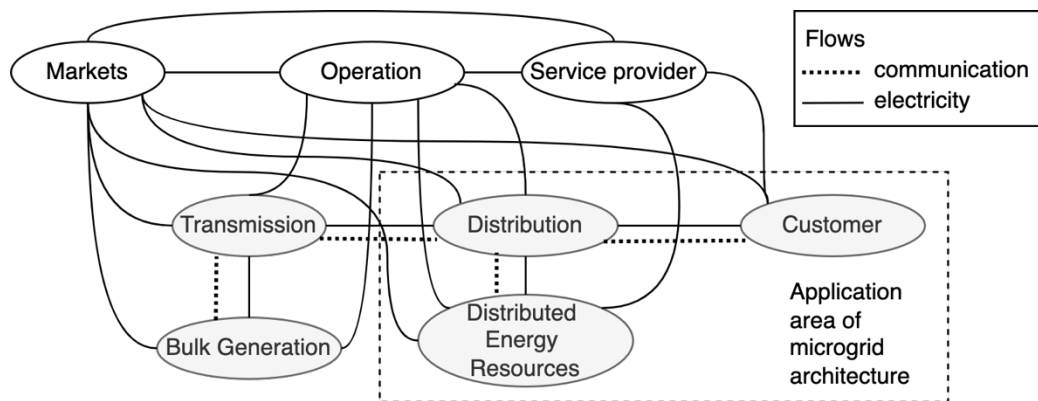


Fig. 1. Conceptual model of smart grid domains and corresponding flows [1]. Note that Markets, operations are zones, service provider represents a group of actors which has universal role (the role is defined by the particular use case) in the context of smart grid

A schematic view of microgrids, its components and relations is provided on Fig. 2. A micro-grid system provides following major functions:

- **Monitoring and control** of the micro-grid in real time (SCADA)
- **Distribute** electricity to any micro-grid users
- **Protect and maintain** the related micro-grid assets

- **Ensure balance** of demand and supply
- **Handle islanding**, connection and disconnection

Based on distribution and DER domains and process zone which includes the micro-grid primary devices, a micro-grid system needs to maintain its stability, voltage, frequency and reliability.

Micro-grid can operate two basic modes:

- **Grid connected mode** – Micro-grid is interconnected with macrogrid, offers various support functions such as Peak Management, Responsive Reserves, Grid Voltage Support (*VARs*), Backup Emergency Power, Islanding on requests/emergency.
- **Island mode** – Micro-grid operates as disconnected/isolated from macro grid, a micro-grid system may be called on to perform the following functions: Grid Synchronizing & (re-) Connection, Balancing Supply & Demand, Active/Reactive Power Compensation/Voltage Control Economic Dispatch, Load Control.

Architectures for microgrids as they need to manage the energy flows from different types of sources, can be classified into three topologies:

- **AC microgrid** – Uses AC bus. Power sources with AC output use AC/AC converter to transform the voltage (and eventually frequency) and DC power sources use DC/AC converters to connect to the bus.
- **DC microgrids** – Uses DC bus. Power sources connect to bus using DC/DC or AC/DC converters.
- **Hybrid microgrids** – Has both buses, which are connected to each other through a bidirectional converter.

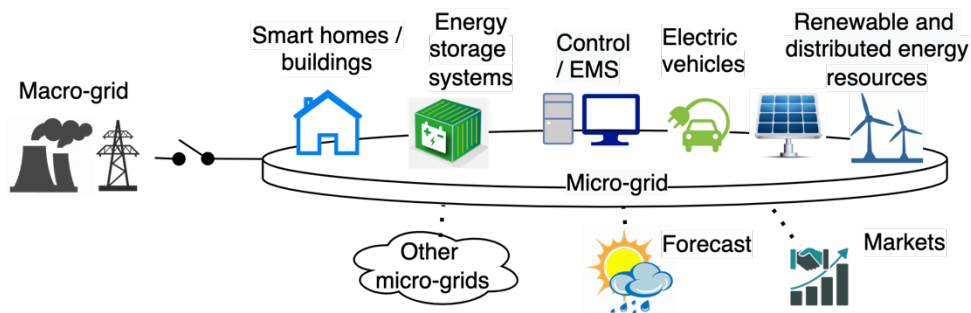


Fig. 2. Schematic view of microgrid, its components and relations

So far, we have explicitly spoken about electricity, but smart grid is not limited to electricity and enables optimizations that interconnect all the energy forms, its transformation, and synergies.

Considering this, the basic components categories in microgrid are:

- **Power sources** - Microgrid presents various types of generation sources that feed electricity, heating, and cooling to the user. These sources are divided into two major groups – thermal energy

sources (e.g, natural gas or biogas generators) and renewable generation sources (e.g., wind turbines and solar). There can be also combination e.g. combined heat and power produced using cogeneration units.

- **Power consumption** - Simply refers to elements that consume electricity, heat, and cooling. This can be single devices, lighting and heating systems of buildings, commercial centers, etc.
- **Energy storage** - Includes all types of storage technologies, such as chemical, electrical, pressure, gravitational, flywheel, heat. Energy storage performs multiple functions, e.g.:
 - Ensures power quality, including frequency and voltage regulation.
 - Smoothes the output of renewable energy sources.
 - Provides backup power for the system.
 - Plays a crucial role in cost optimization.

2 Microgrid and EMS systems

Microgrid is a place, where much can be gained and lost. Lot of effort has been but and yet will be put into optimization of microgrid structure and control.

Power sources and loads can be controllable so the consumption/generation can reflect demands of the network. Moreover, storages offer additional degrees of freedom for control strategies.

When multiple energy storages with various capacities, technologies and resulting properties are available in a microgrid, it is advantageous to coordinate their charging and discharging to achieve original parameters of the system.

Systems designed to such optimizations are called energy management systems (*EMS*) or home energy management systems (*HEMS*), building energy management systems (*BEMS*) according to used deployment. Often such systems have hierarchical control. Generally, there are two main control strategies – **centralized** and **decentralized**.

They both have advantages and disadvantages, see Tab. 1 for sample details.

Tab. 1 Main advantages and disadvantages of centralized and decentralized microgrid control

System	Centralized control	Decentralized controls
Advantage	Proper coordination and leadership, global information	Local measurement and regulation, easy implementation
Disadvantage	Single Point of failure (SPOF)	Lack of global information

For micro-grid a **hierarchical** control is often adopted because it introduces a certain degree of independence between different control levels. It is more reliable as it continues to be operational even in the case of failure of the centralized control.

Hierarchical control introduces 3 levels of control [2]:

- **Primary control** copes with instant power sharing control and current/voltage regulations.
- **Secondary control** has slower reaction time (seconds to minutes), deals with the voltage compensation and balancing, power quality requirements.
- **Tertiary control** has slowest reaction time (minutes to hours), performs power/energy management, system optimization, considers pricing factors. Often involves prediction of weather, tariffs, loads and aims to achieve economic savings. Techniques such as deep neural networks are considered here.

As the reaction time grows in the control levels, the necessary communication bandwidth decreases. This allows appropriate hierarchical solutions and services which can use modern concepts on ICT as virtualization, cloud-based services and communication platforms.