Aalto University
School of Engineering

Distributed Generation Technologies

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Chapter3:
Distributed Generation Technology and it's Application in Power System (i.e., Microgrids and Smart Grids)

The Main Objectives of this Session:

At the end of this session students will be able to answer the following questions:

1. What is the meaning of Distributed Generation (DG) technology?
2. What is the application of DG technology in power network?
3. What kind of technology is used for integration of DG sources into the power grid?

What is Distributed Generation (DG)?

DG is technique of generating electricity on a small scale from renewable and non-renewable energy sources that is on-side or close to the load center.

https://www.youtube.com/watch?v=YAisP5ZBAWA

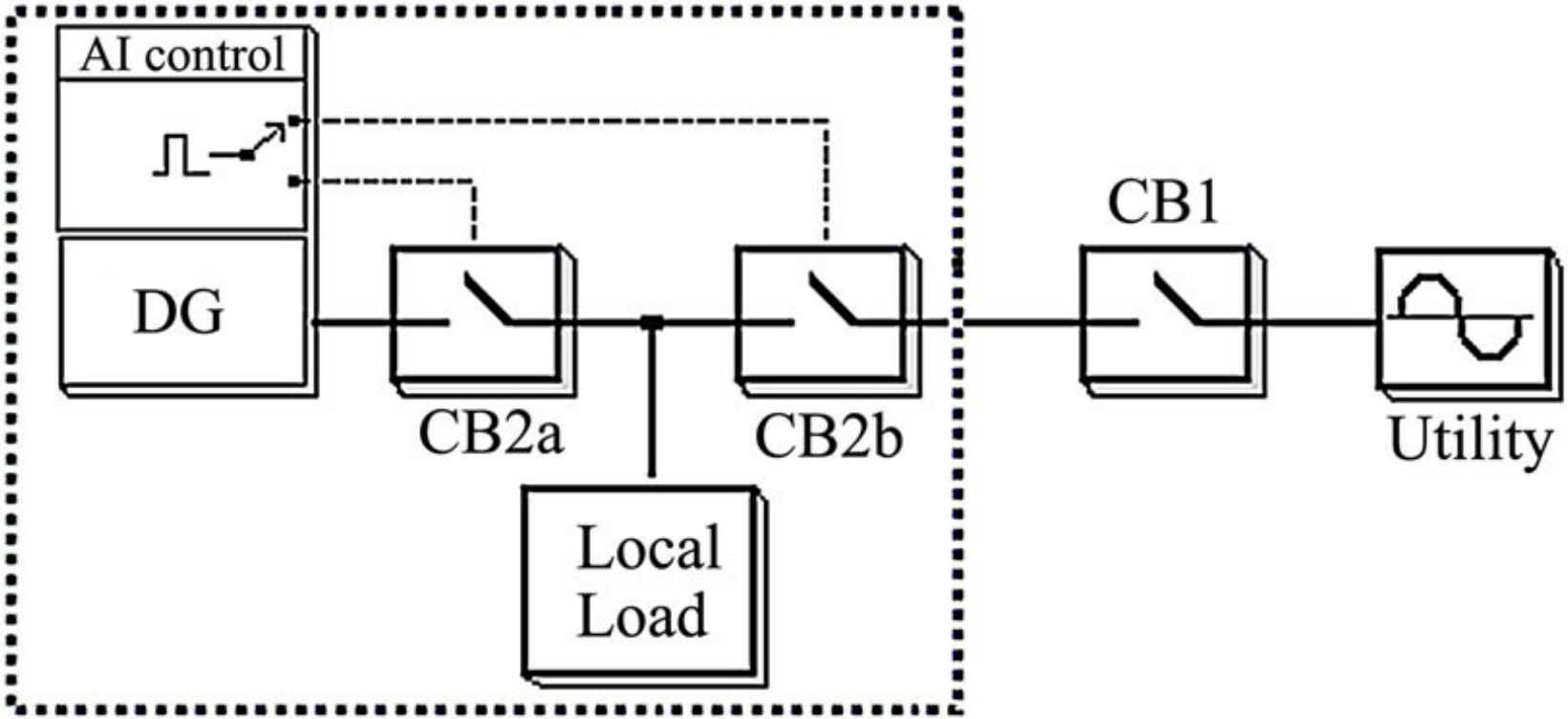
Advantages of DG Technologies

- Increases reliability, and security of the grid.
- Can be configured to match customer demand.
- Diversifies the range of energy sources used.
- Reduces the necessity to build new transmission or distribution lines.
- Reduce carbon emissions and emissions of other air pollutants.
- Increase asset use through integration of distributed systems and customer loads to reduce peak load and thus price volatility.
- Improve system efficiency with on-site DG and improve economic efficiency through demand-side management.

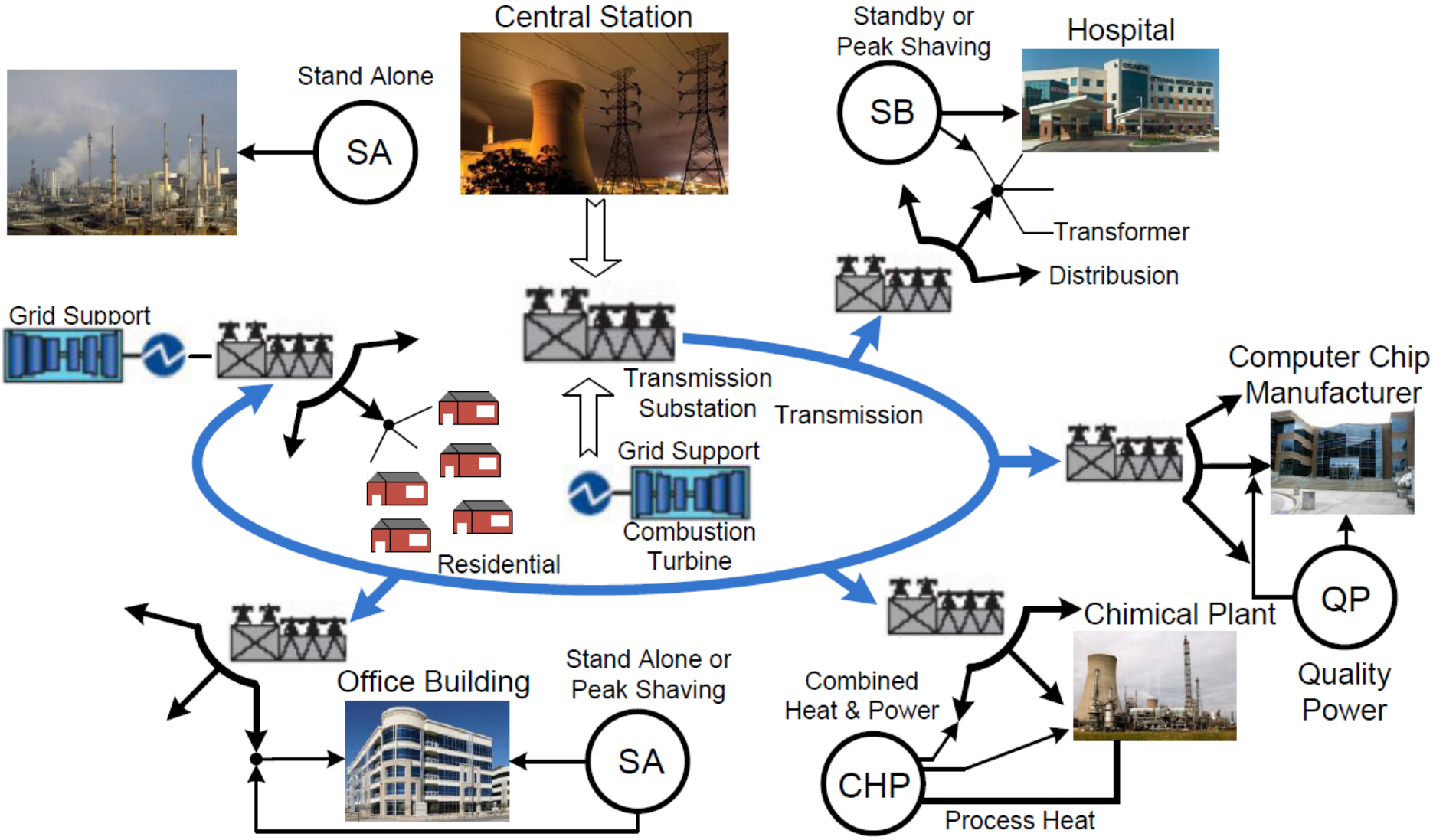
Role of DG Technologies in our Electrical Network

https://www.youtube.com/watch?v=maAmap5kb3k&list=PLqxO2CvERBWUlAUlyzhB0DT5GC7CQ_mEa&index=2

DG Integration



Application of DG Technologies in Power Systems



Application of DG Technologies in Power Systems

https://www.youtube.com/watch?v=mtkyetyCfSg

DG System Configuration

Generation units = microsources (Normally less than 100 kW, but can be up to 10,000 kW)

- PV Modules
- Small wind generators
- Fuel Cells
- Microturbines

Energy Storage (power profile)

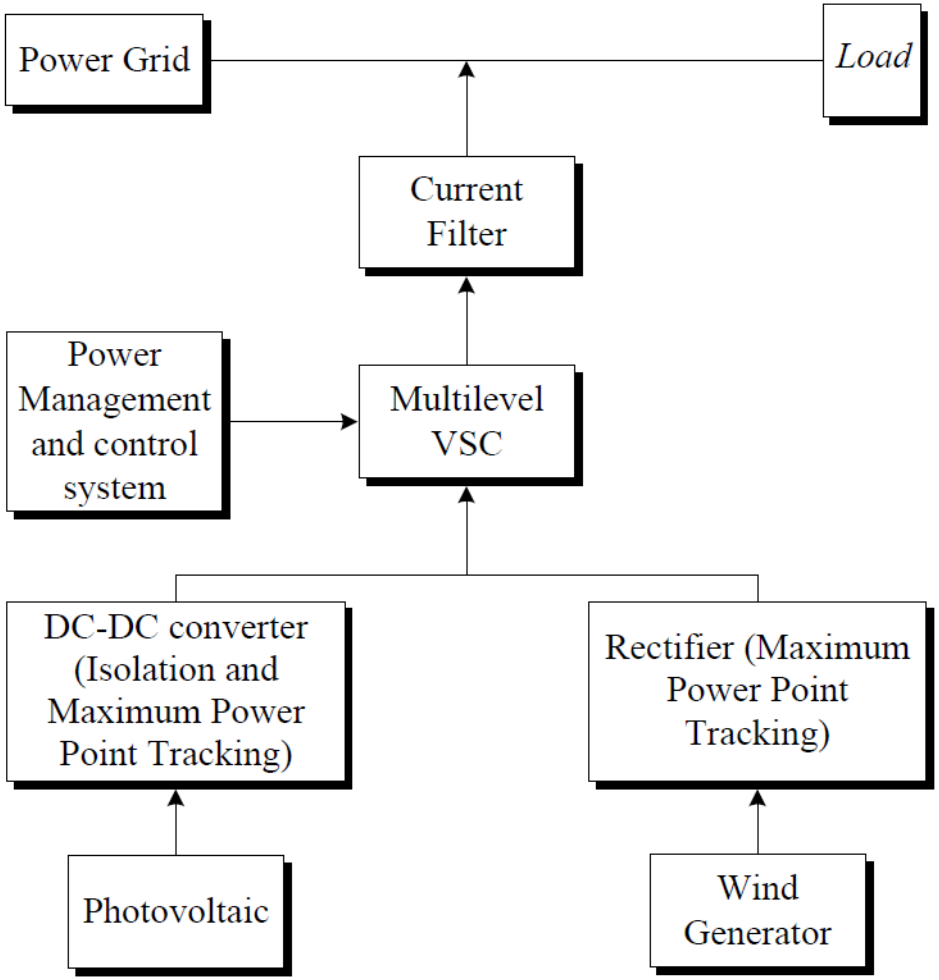
- Batteries
- Ultracapacitors
- Flywheels

Loads

- Electronic loads
- Plug-in hybrids
- The main grid

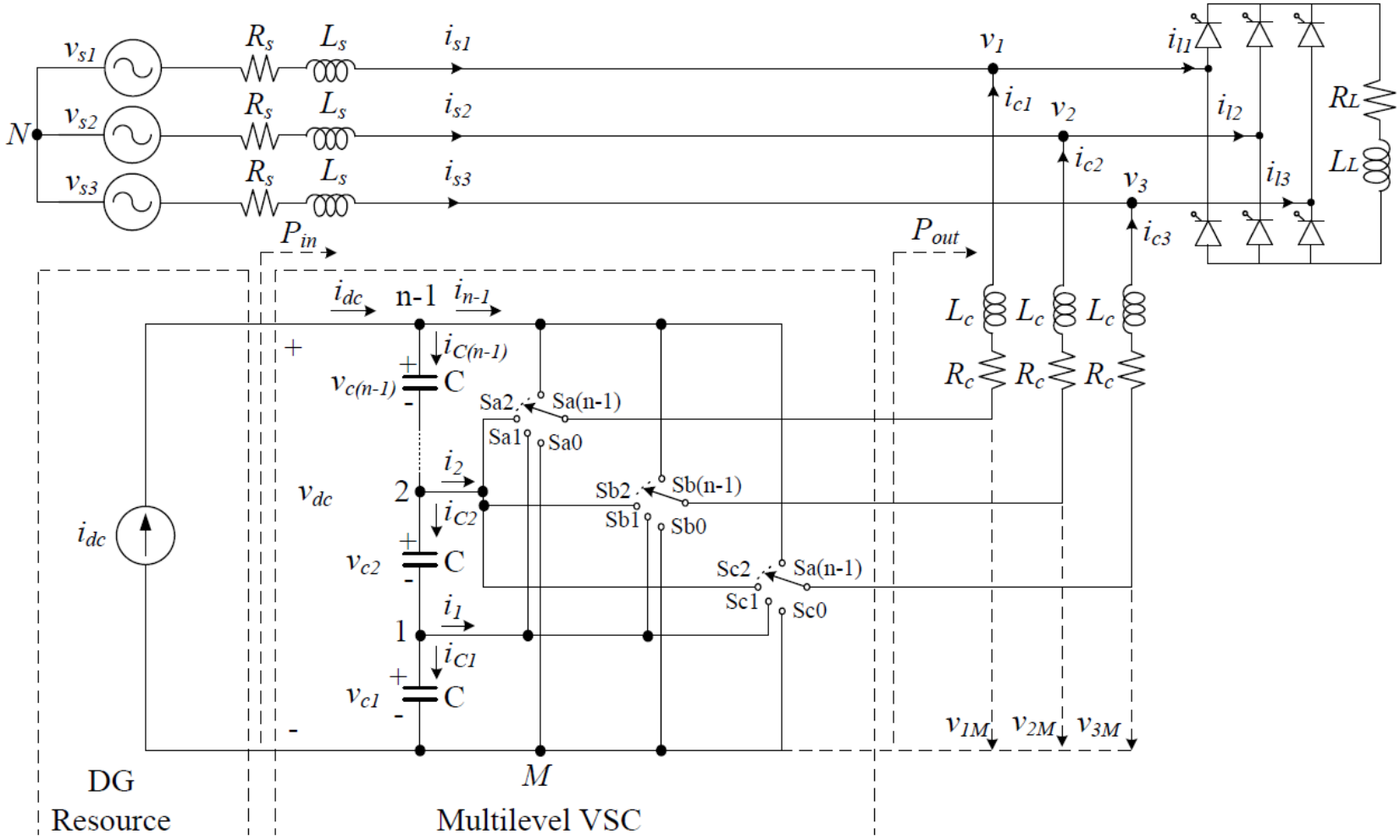
Power electronics interfaces

- dc-dc converters
- dc-ac converters
- Rectifiers



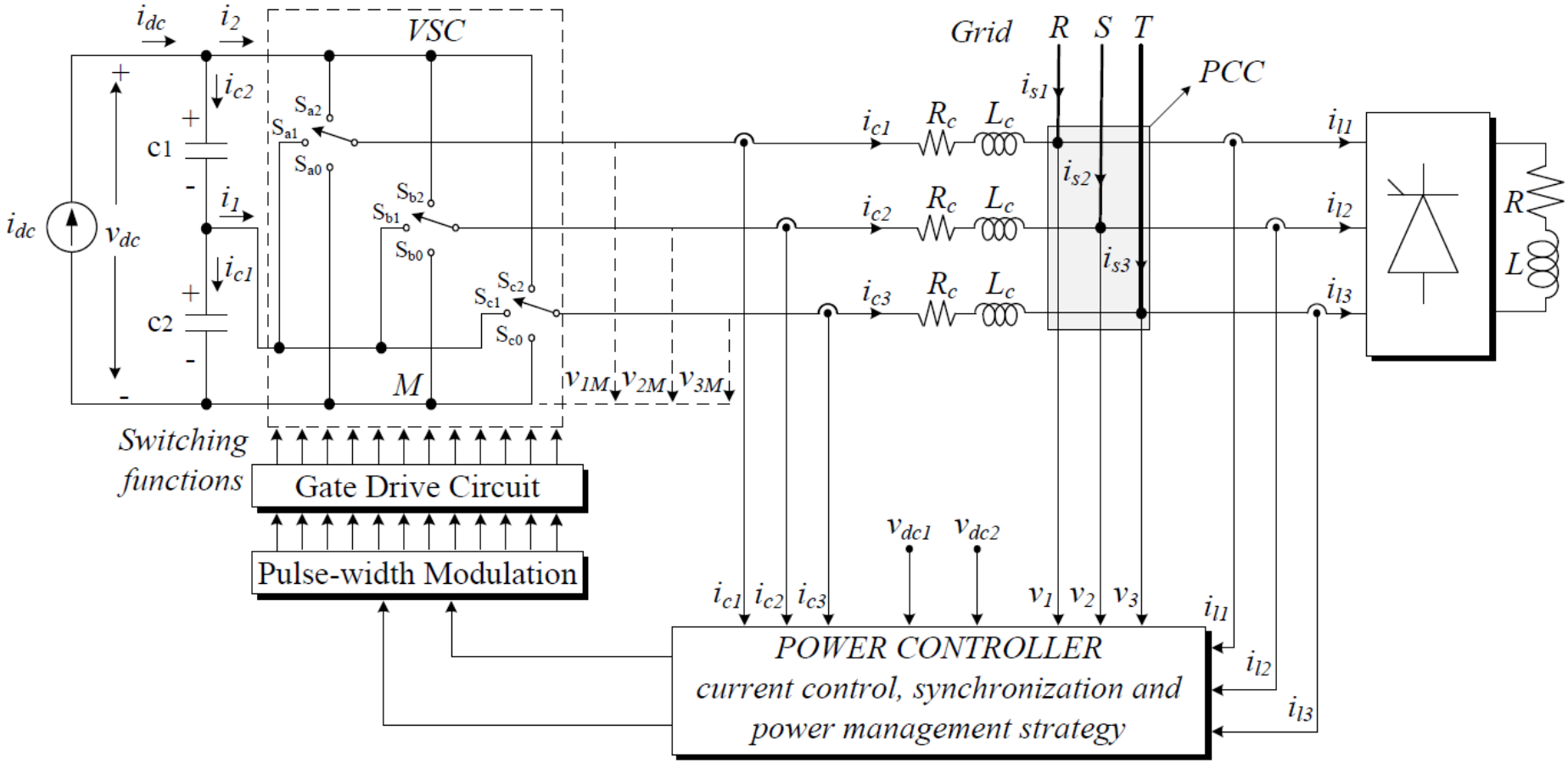
General Configuration of DG System

Configuration of a Grid-Connected DG System



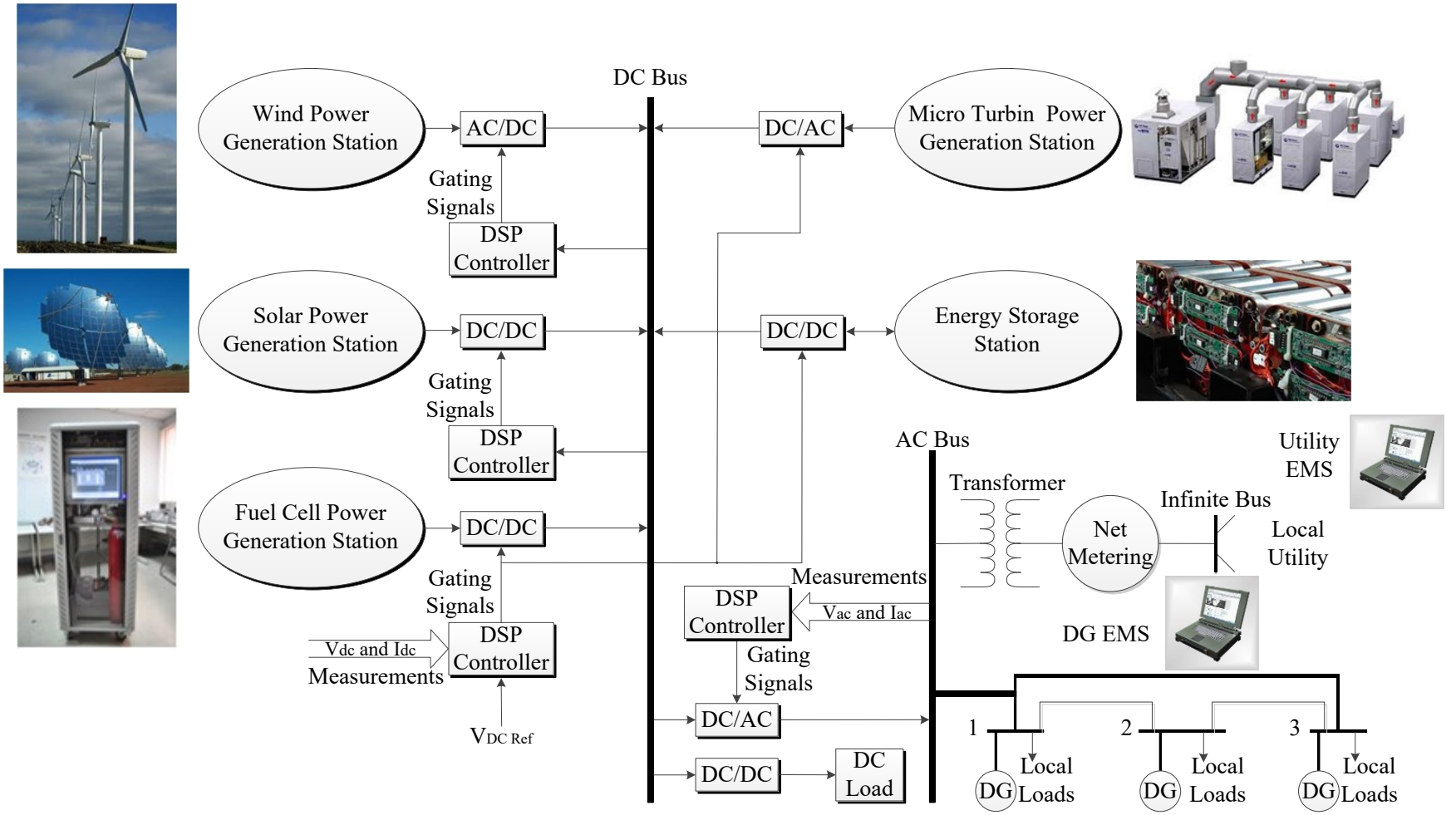
General Structure of a Grid-Connected DG System

Detailed Configuration of a Grid-Connected DG System



General Structure of a Grid-Connected DG System Including the Control Loop

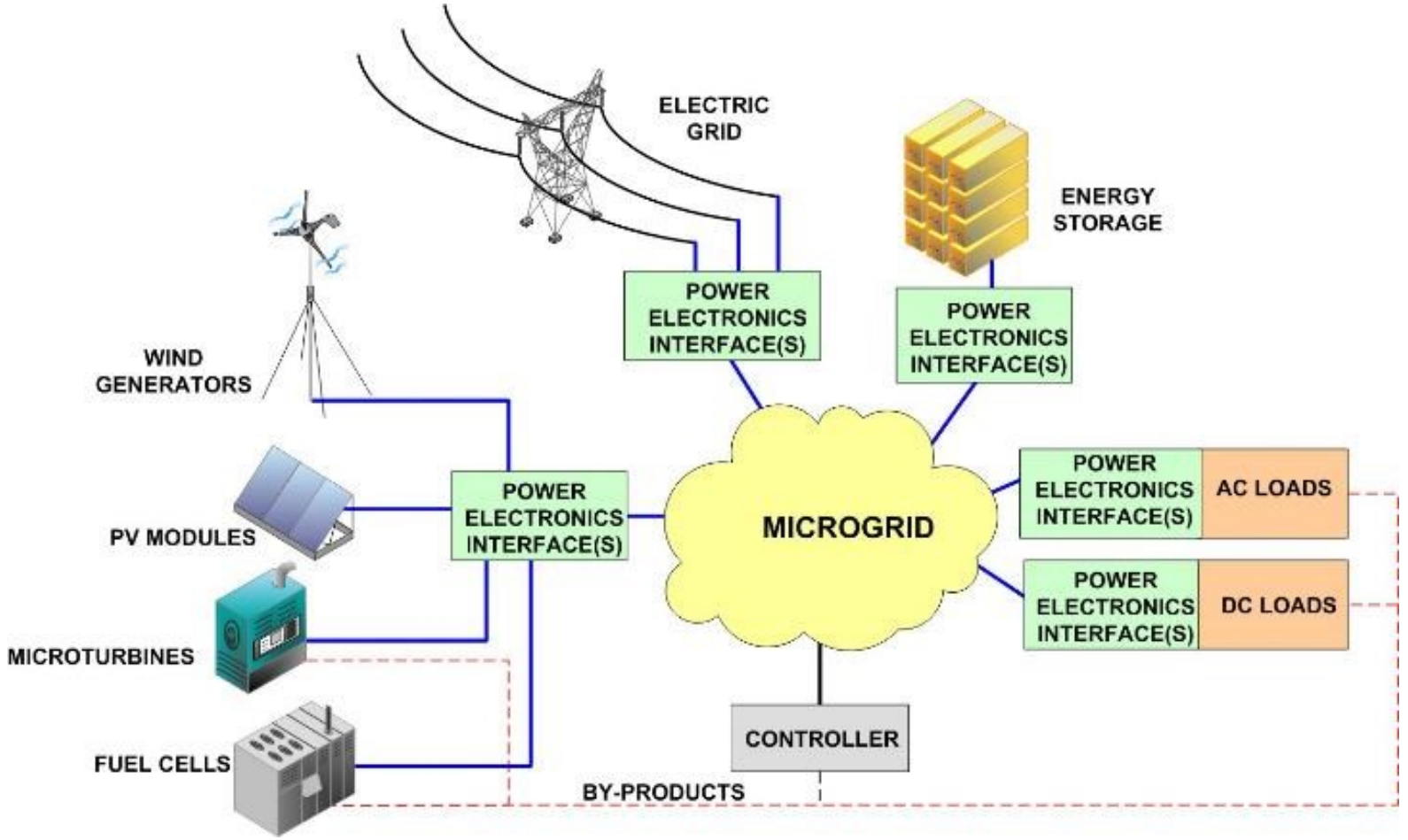
Classification of Power Electronics Interfaces



Application of Different Converter Interfaces for Integration of DG Sources into the Loads and/or Grid

Power Electronic Interfaces

- Power electronic converters provide the necessary adaptation functions to integrate all different DG units into a common system.



Application of Different Converter Interfaces for Integration of DG Sources into the Loads and/or Grid

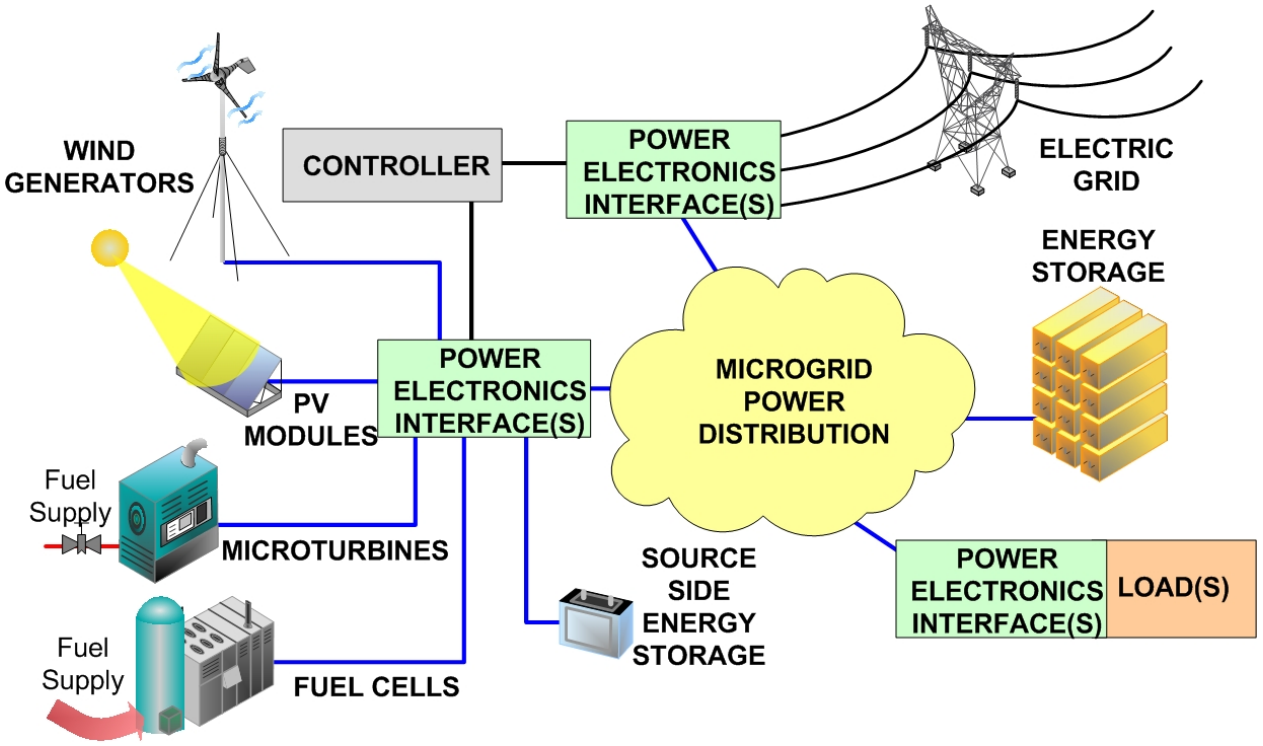
Distributed Generation and Microgrid

What is Microgrid?

- A microgrid is a small-scale power supply network that is designed to provide power for a small community.

What is Microgrid?

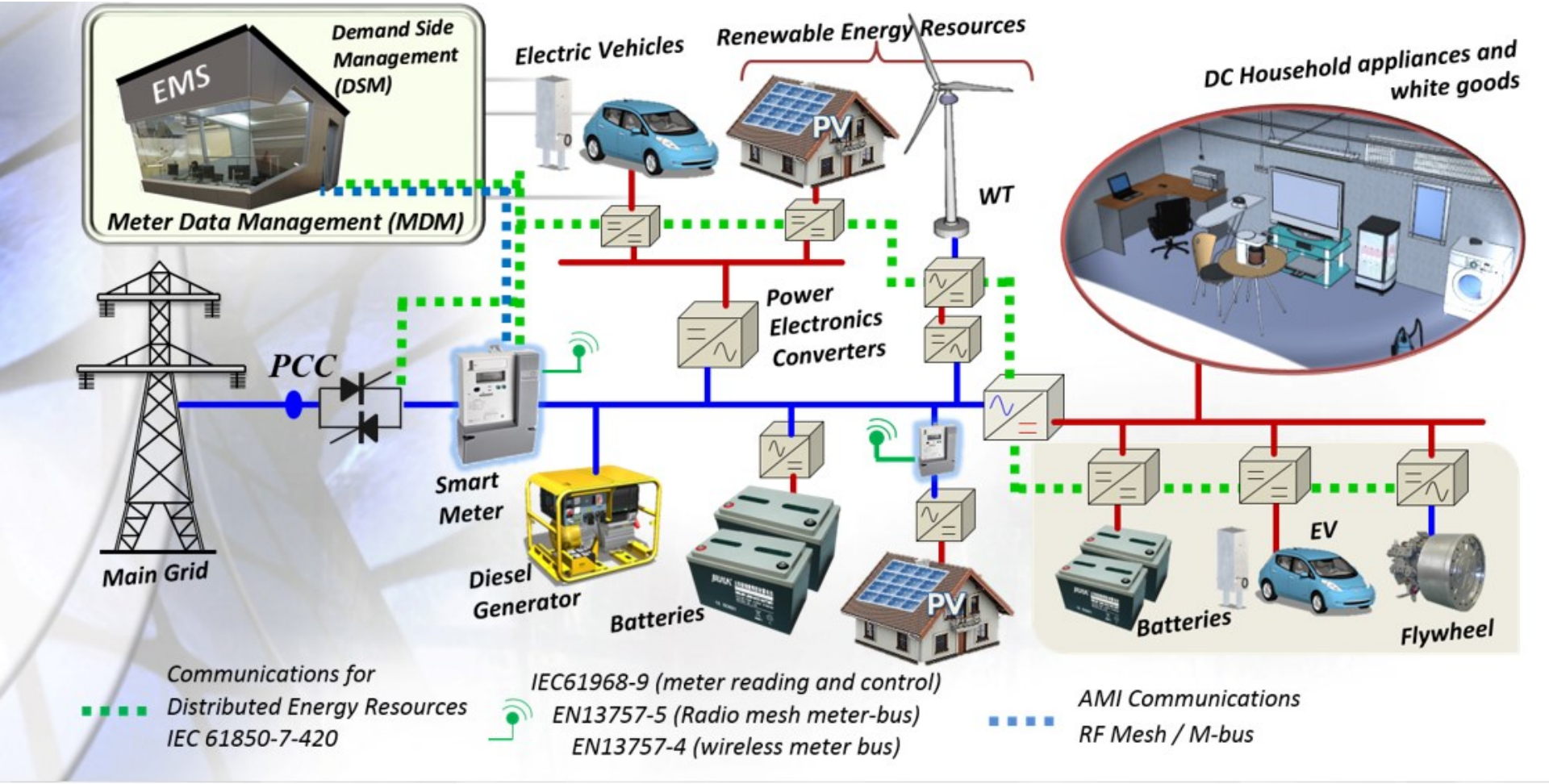
- **Microgrids** are local electrical systems that combine retail loads and distributed generation resources. A microgrid may include integrated management of thermal and electrical loads, thermal and electrical storage, or a "smart" interface with the grid, operating in parallel or in isolation from the grid.



Microgrids: Evolving the Power Grid

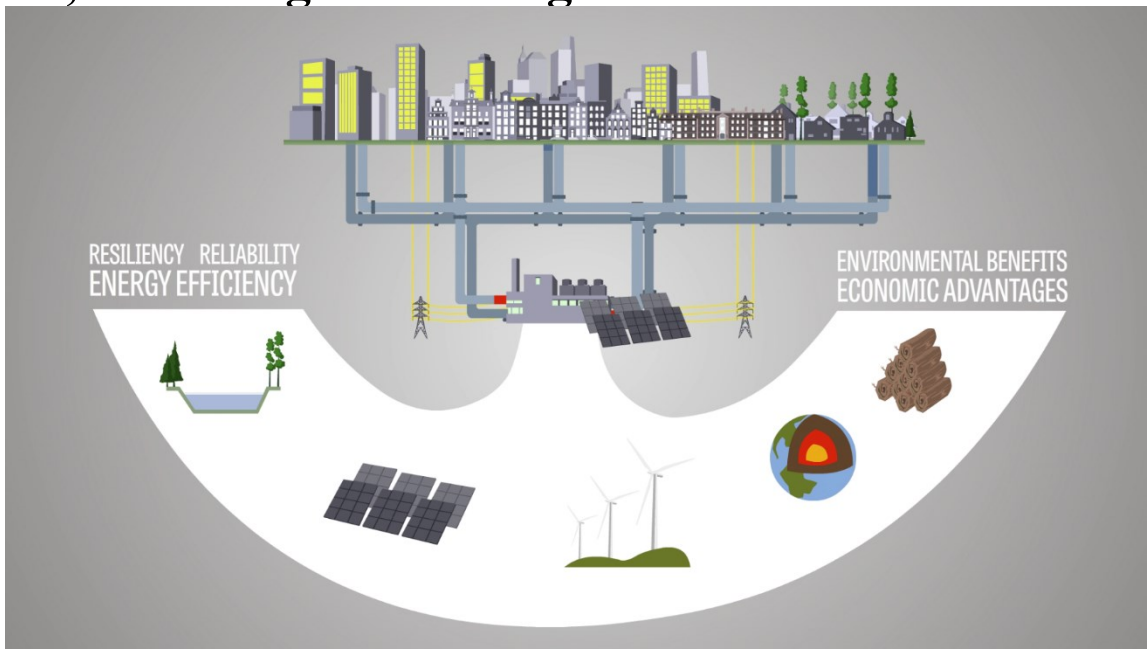
https://www.youtube.com/watch?v=cVuQsskKlTk

Schematic diagram of Microgrid



Distributed Generation: Advantages with Microgrid

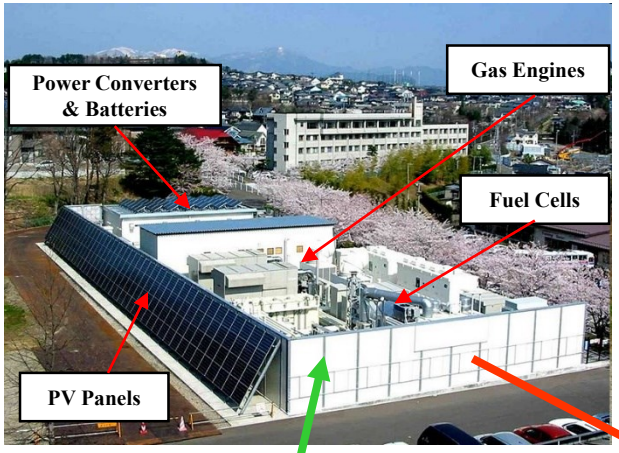
With respect to the traditional grid, well designed Microgrids are:



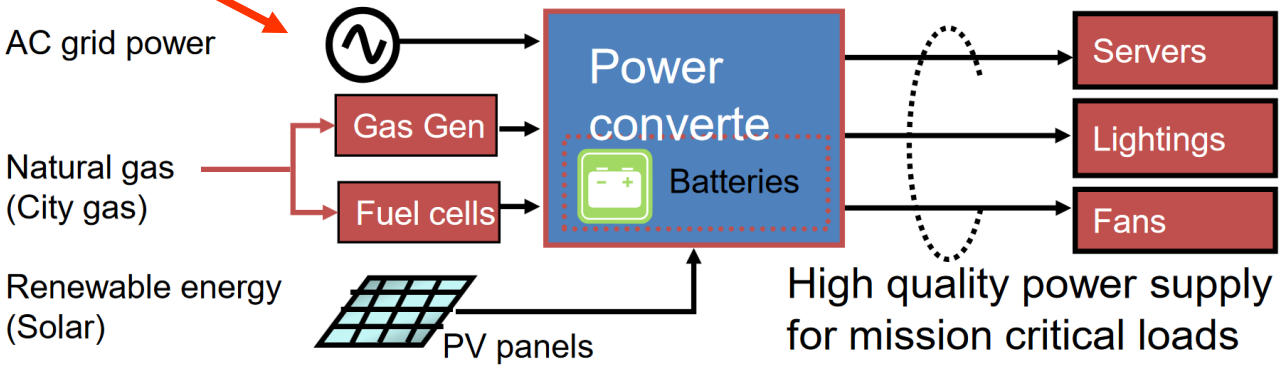
- More reliable
- More resilience
- More efficient
- More environmentally friendly
- More flexible
- More Secure
- More modular
- Easier to control
- Secure to issues occurring elsewhere
- Capital investment can be scaled over time
- Microgrids can be integrated into existing systems without having to interrupt the load
- Microgrids allow for combined heat and power (CHP) generation

Microgrid Example: 1

- **Resilient power supply during disasters**
  - **Microgrid** constructed in Sendai city to supply high quality power for mission critical loads.
  - Power electronic enabled micro-grids can be the solution that achieves reliable power during disasters (e.g. NTT's micro-grid in Sendai, Japan).



Sendai Microgrid



Microgrid Example: 2

- **Isolated microgrids for remote areas: Villages in Alaska**
- Wind is used to supplement diesel generators (diesel is difficult and expensive to transport in Alaska)

http://avec.org/wp-content/uploads/2014/11/Toksook-Wind-Tower-Bulk-Fuel-and-Power-Plant.jpg

• **Toksook Bay**

•Current Population: 638

•Incorporation Type: 2nd Class City

•Total Generating Capacity (kw): 2,018

- •1,618 kW diesel
- • 400 kW wind
- •(tieline to Tununak and Nightmute)

Information from "Alaska Village Electric Cooperative"

Microgrid Example: 3

A microgrid with combined heat and power can be used in factories to overcome power quality issues affecting product quality in manufacturing processes.

Microgrid Example: 4

- Kitakyushu smart community (Japan)

Microgrid Example: 4

- Kitakyushu smart community (Japan)
  - Peak power consumption of this area = 18 MW.
  - Main power source: 30 MW from a natural gas generator at steel mill.

Microgrid Example: 4

- Kitakyushu smart community (Japan)
  - The area has a few 3 kW wind generators.

Microgrid Example: 4

- Kitakyushu smart community (Japan)
  - Most buildings and homes have PV systems.
  - Total peak power generated by PV = 0.5 MW.

Microgrid Example: 4

- Kitakyushu smart community (Japan)

- Hydrogen produced in the industrial area is distributed with a 1.2 km pipeline for:
  - 7 x 3 kW Toshiba residential fuel cells,
  - 3 kW hydrogen station
  - 100 kW fuel cell at a museum.

Microgrid Example: 4

- Kitakyushu smart community (Japan)
  - Residential fuel cells

Deodorant and flow meter

Fuel Cell

Hot water storage

Microgrid Example: 4

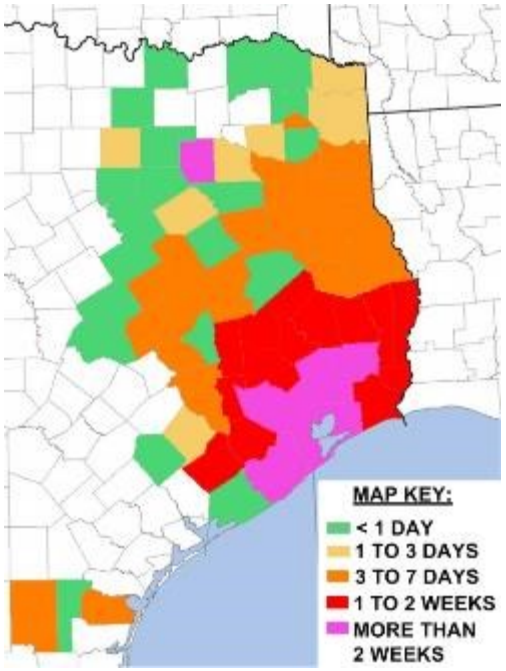
- Kitakyushu smart community (Japan)
  - EV fast charging (and discharging) station + 50 kWh Li-ion batteries.

Microgrid Example: 4

- Kitakyushu smart community (Japan)
  - 300 kWh Lead-acid batteries.

Microgrids and Grid Resiliency

- Power grids are extremely fragile systems.
- Power supply issues during disasters is a grid's problem transferred to the load.



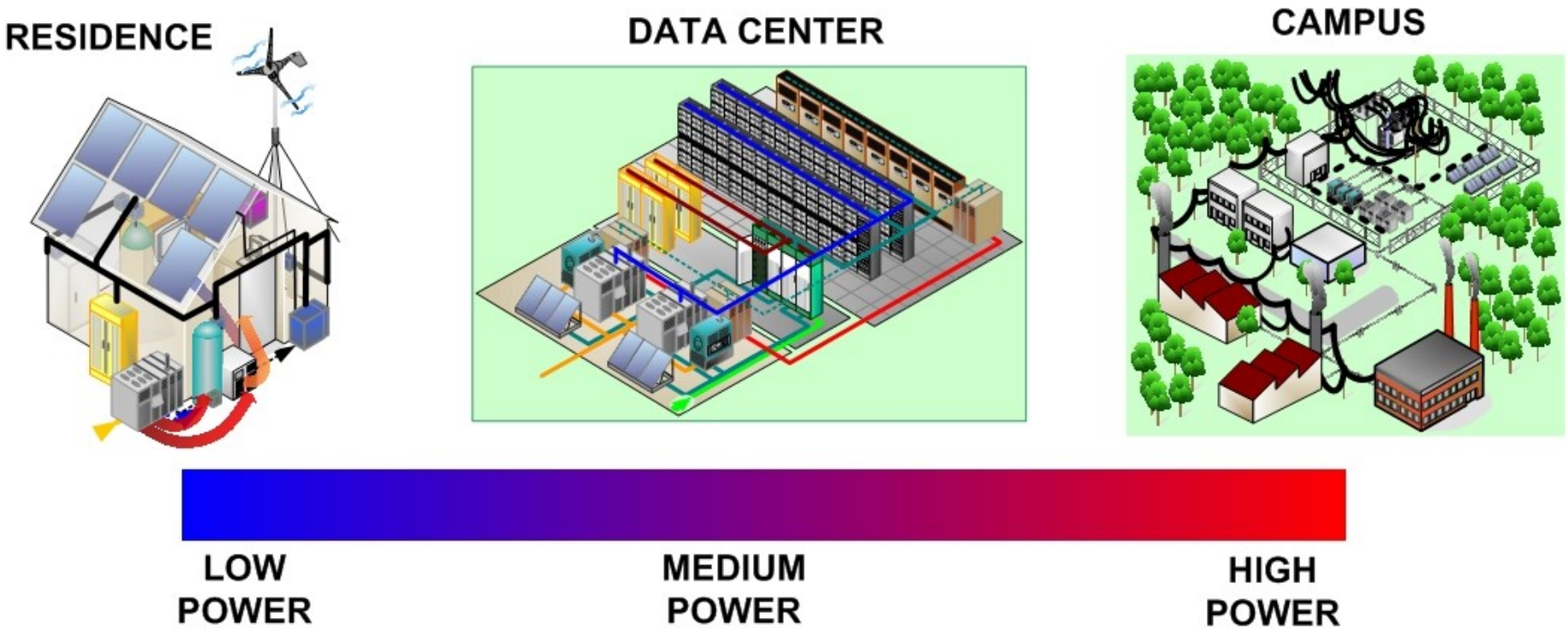
Microgrids and Grid Resiliency

- Common concept of damage to the electric grid during disasters:

- Real sustained damage in more than 90 % of the area:

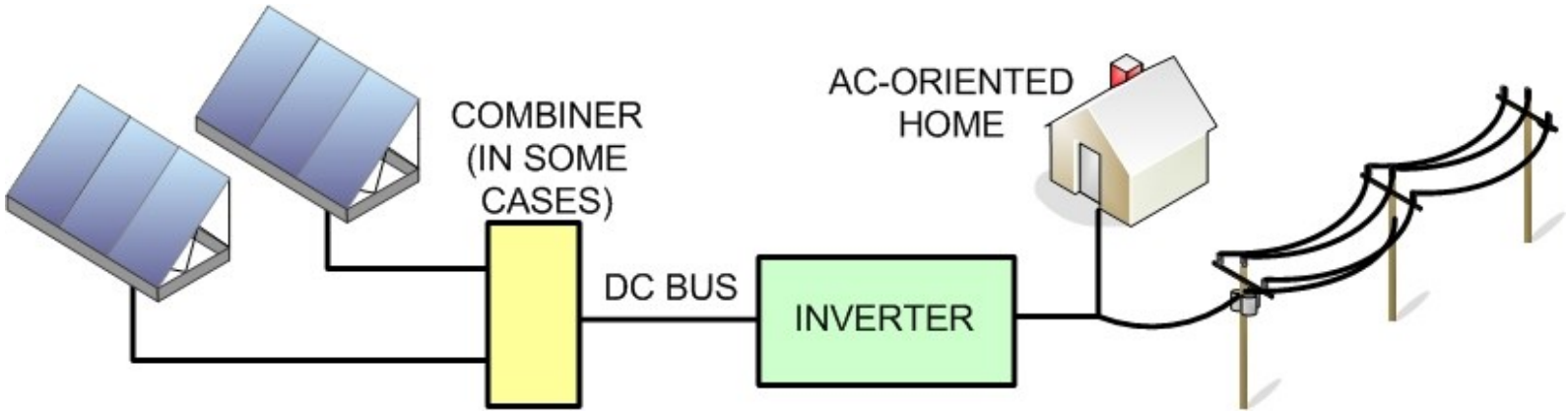
DG Units Application Range

Normally, DG sources are used from a few kW to MW.



What is not a microgrid?

- Residential conventional PV systems (grid-tied) are not microgrids but they are distributed generation systems.
- Why are they not microgrids? Because they cannot operate isolated from the grid. If the grid experience a power outage the load cannot be powered even when the sun is shinning bright on the sky.



Distributed Generation and Smart Grids

- European concept of smart grids is based on electric networks needs:

  • **Flexible:** fulfilling customers' needs while responding to the changes and challenges ahead;

  • **Accessible:** granting connection access to all network users, particularly for renewable power sources and high efficiency local generation with zero or low carbon emissions;

  •**Reliable:** assuring and improving security and quality of supply, consistent with the demands of the digital age with resilience to hazards and uncertainties;

  • **Economic:** providing best value through innovation, efficient energy management and 'level playing field' competition and regulation

- The US concepts rely more on advanced interactive communications and controls by overlaying a complex cyberinfrastructure over the existing grid. DG is one related concept but not necessarily part of the US Smart Grid concept.

Smart grids definition:

Smart grid is an electrical grid that intelligently predicts and responds to the behaviors of electric power users;

So, it efficiently delivers reliable, economic, and maintainable electricity services.

Smart grid focus:

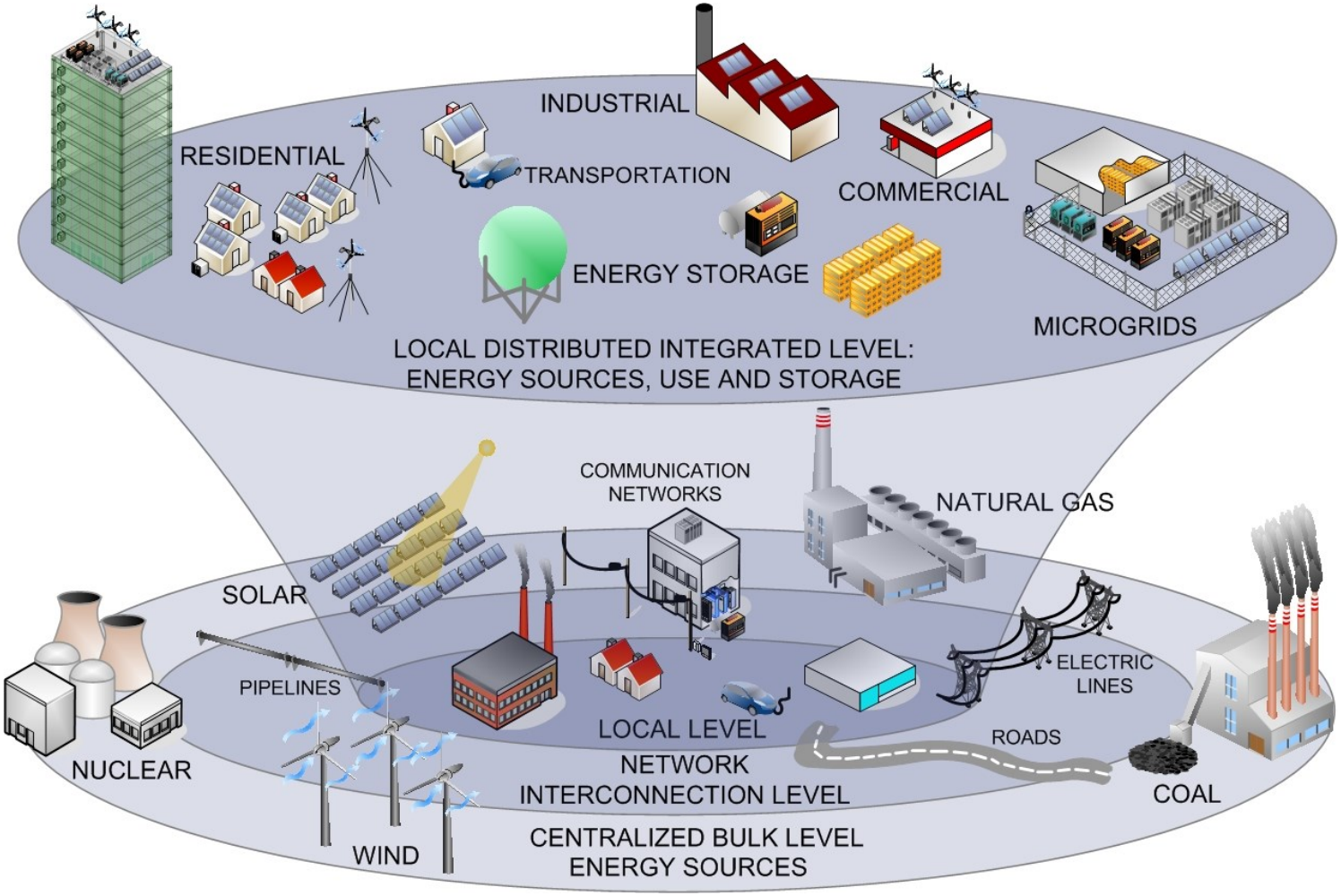
- Reliability.
- Integration of environmentally friendly generation and loads.

Concept evolution:

- "Smart grid 1.0": Smart meters, limited advanced communications, limited intelligent loads and operation (e.g. demand response).
- "Smart grid 2.0" or "Energy Internet": Distributed generation and storage, intelligent loads, advanced controls and monitoring.

Smart Grids

- A customer-centric view of a power grid includes microgrids as one of smart grids technologies.



Smart Grids

https://www.youtube.com/watch?v=JwRTpWZReJk

Questions and comments are most welcome!