Smart Grid Technologies and Applications

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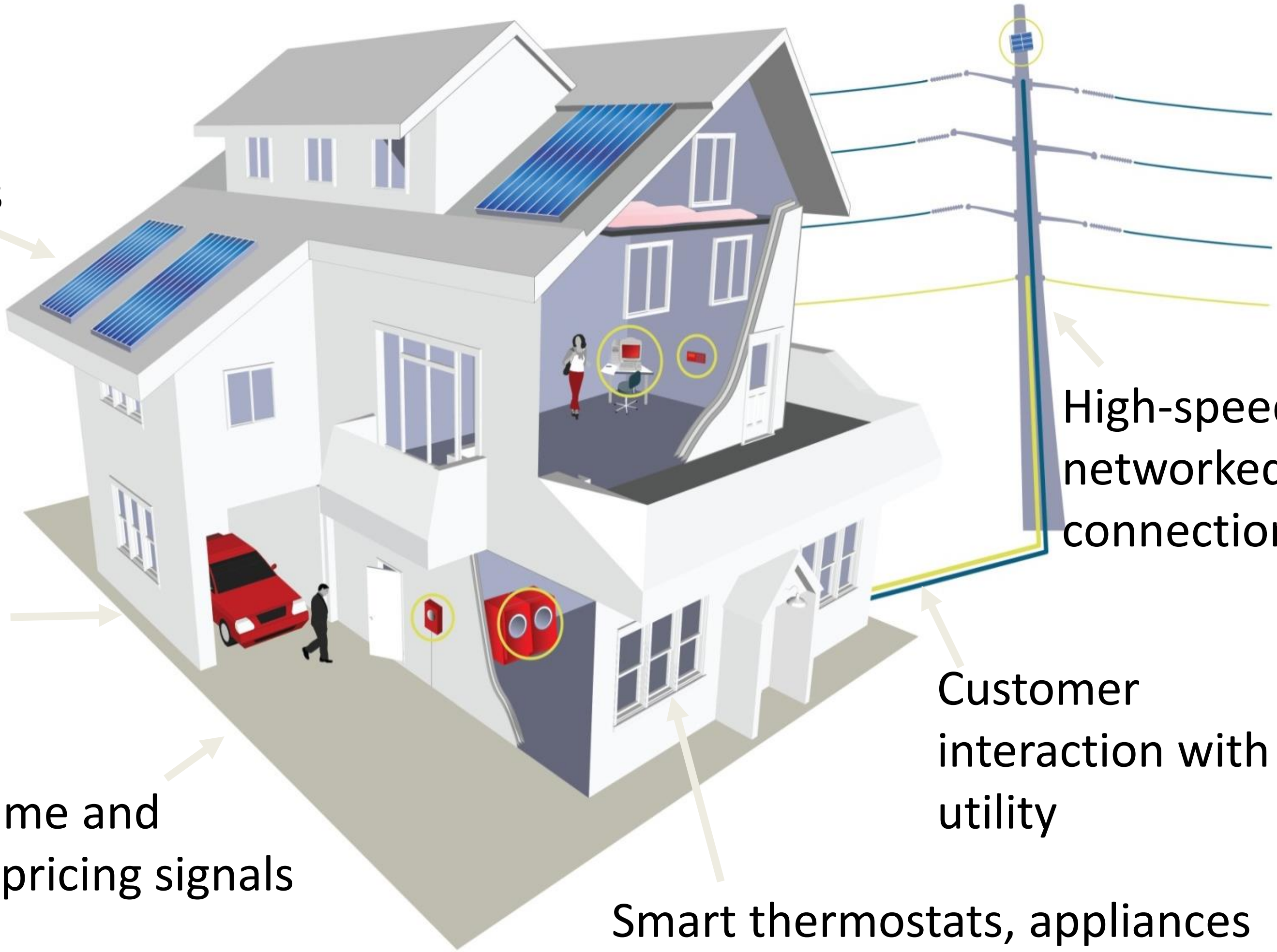
What is the Smart Grid?

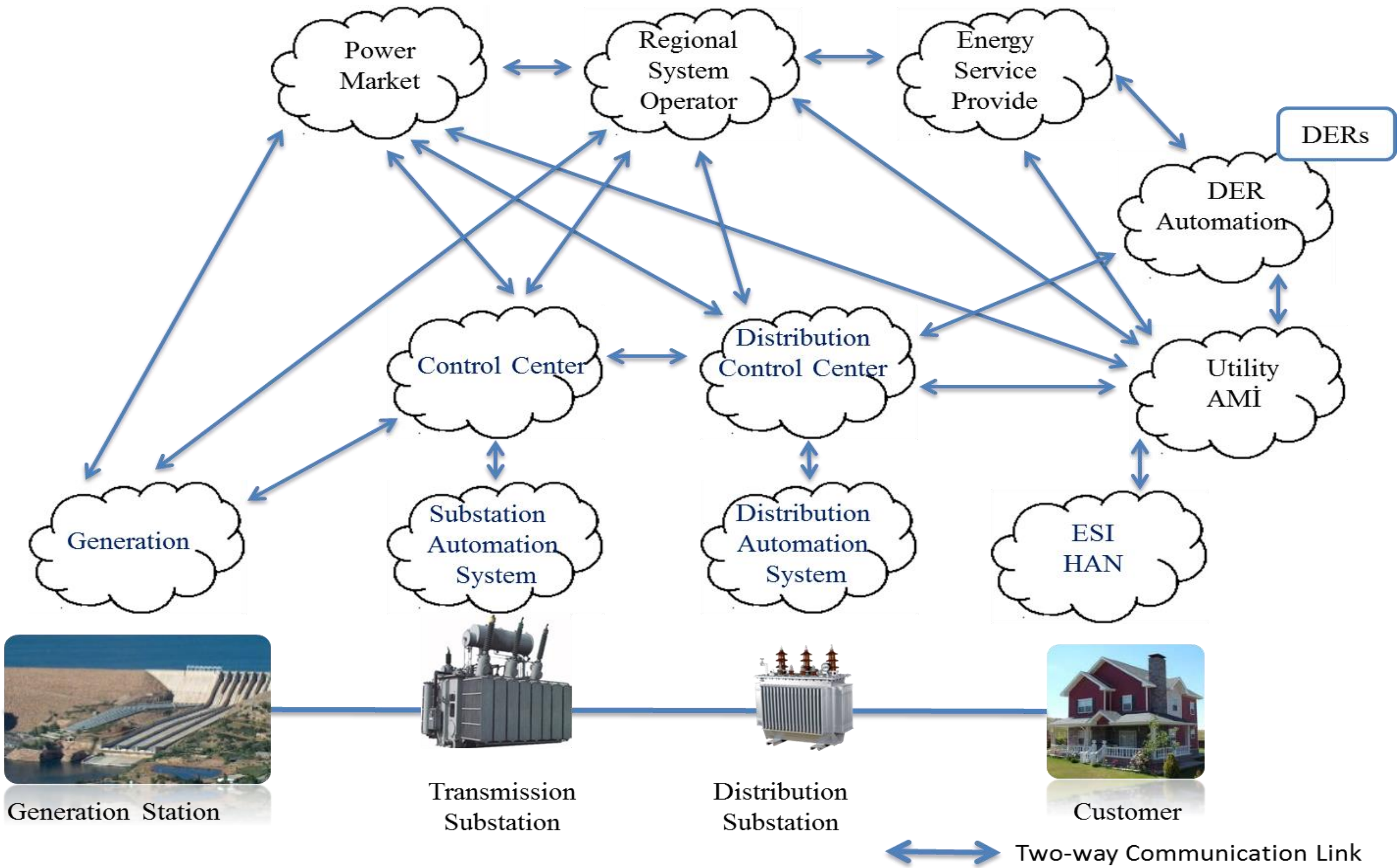
An application of digital information technology to optimize electrical power generation, delivery and use

- Optimize power delivery and generation
- Self-healing
- Consumer participation
- Resist attack
- High quality power
- Accommodate generation options

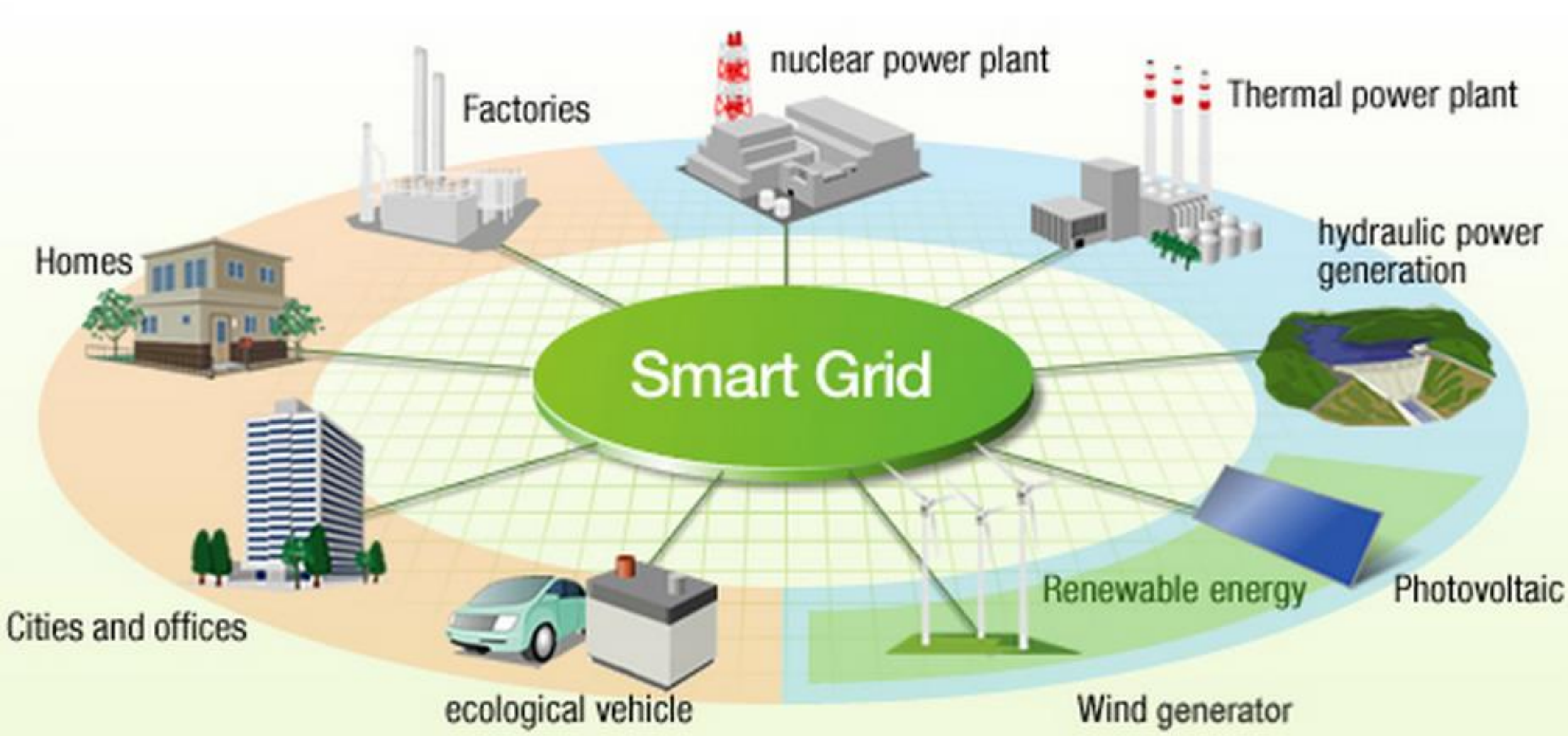
What is Smart Grid?



What is the smart grid?



What is the Smart Grid?



Why Smart Grid ?

- Better situational awareness and operator assistance
- Autonomous control actions
- Efficiency enhancement
- Integration of renewable sources
- Improved market efficiency through innovative solutions for product types
- Higher quality of service

STRUCTURE OF CONVENTIONAL GRID

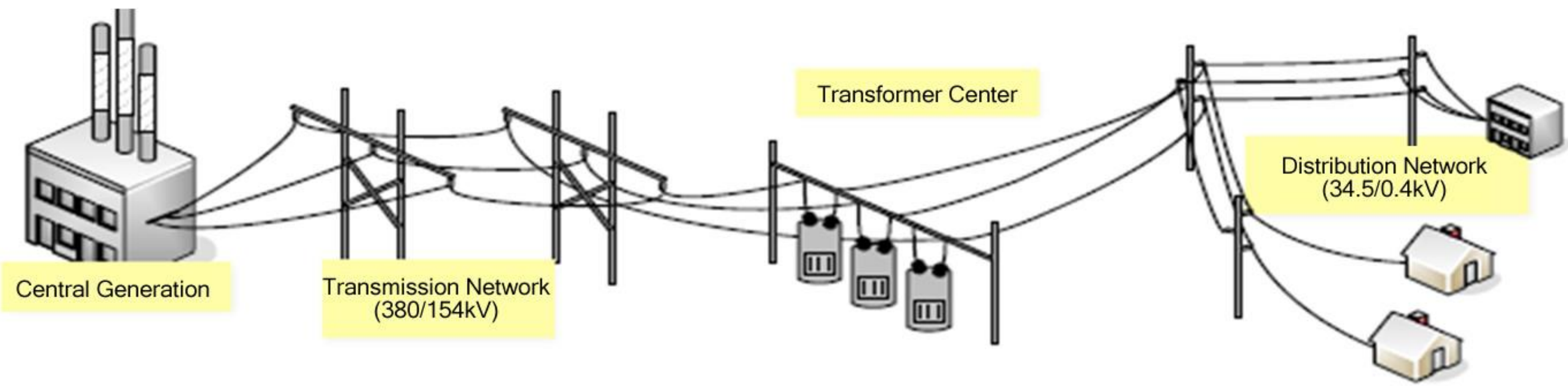
The conventional grid;

- is an interconnected network for delivering electricity from suppliers to consumers,

-consists of generating stations that produce electrical power,

-high-voltage transmission lines that carry power from distant sources to demand centers,

-and has distribution lines that connect individual customers.



There are 3 reasons to convert the conventional grid to smart grid;

The increased energy demand:

- The energy demand is rapidly increased owing to new technologies such as electric vehicles

Decreasing the losses and illegal usages:

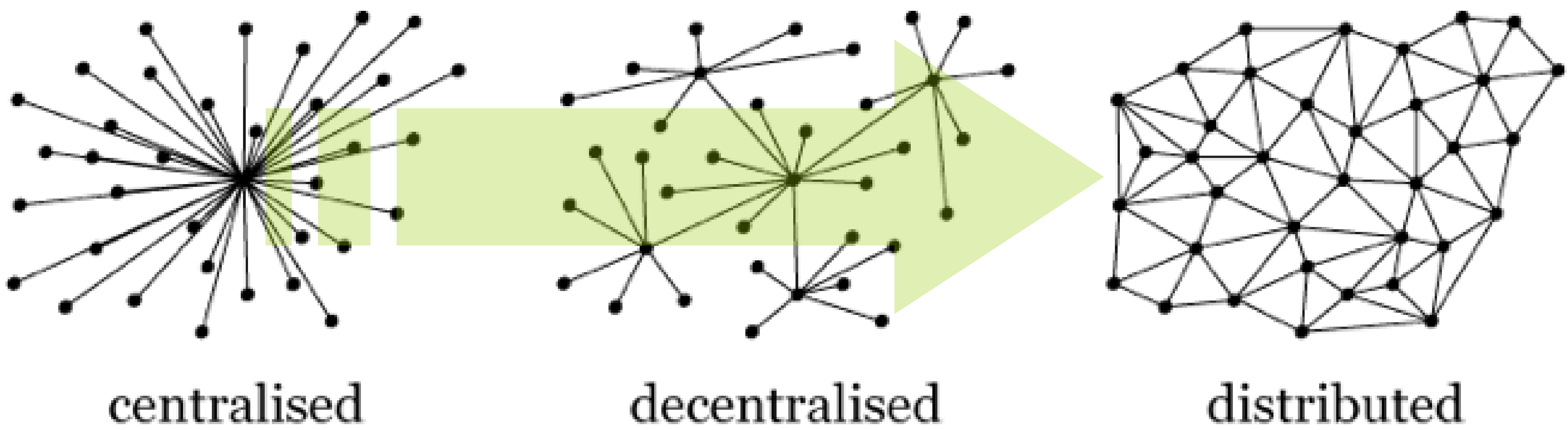
- The losses and illegal usages seen in transmission and distribution lines

The increased producing and carriage capacity in the existing plants:

- In order to meet the increased energy demand,
- To integrate the distributed energy sources such as solar and wind to the system

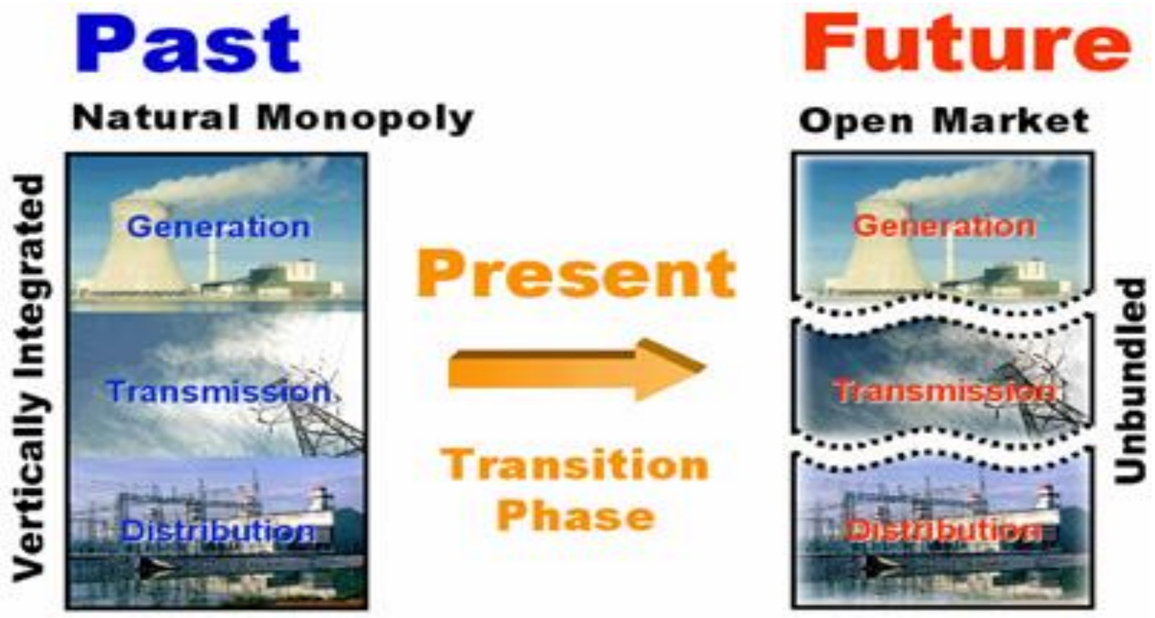
Distributed generation

- The advances in power generation, transmission, distribution, regulation and control techniques have created rapid growth in the utilization of distributed generation.

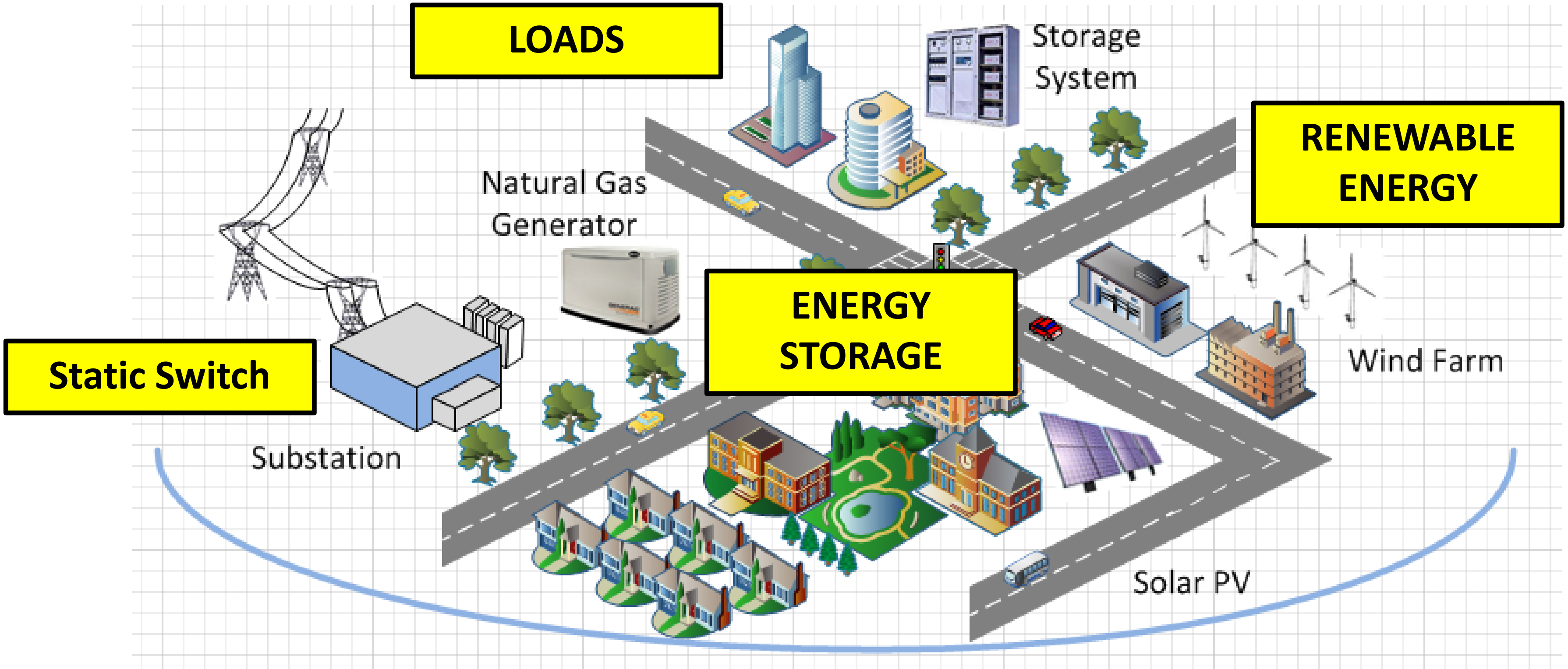


Distributed generation

- This changing in the electric power industry provides the energy market become more attractive and competitive in the world.



What is a Microgrid?



- A group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid.
- A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode.

What is a Microgrid?

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

- It enables local power generation for local loads.

- It contains of various small power generating sources that makes it highly flexible and efficient.

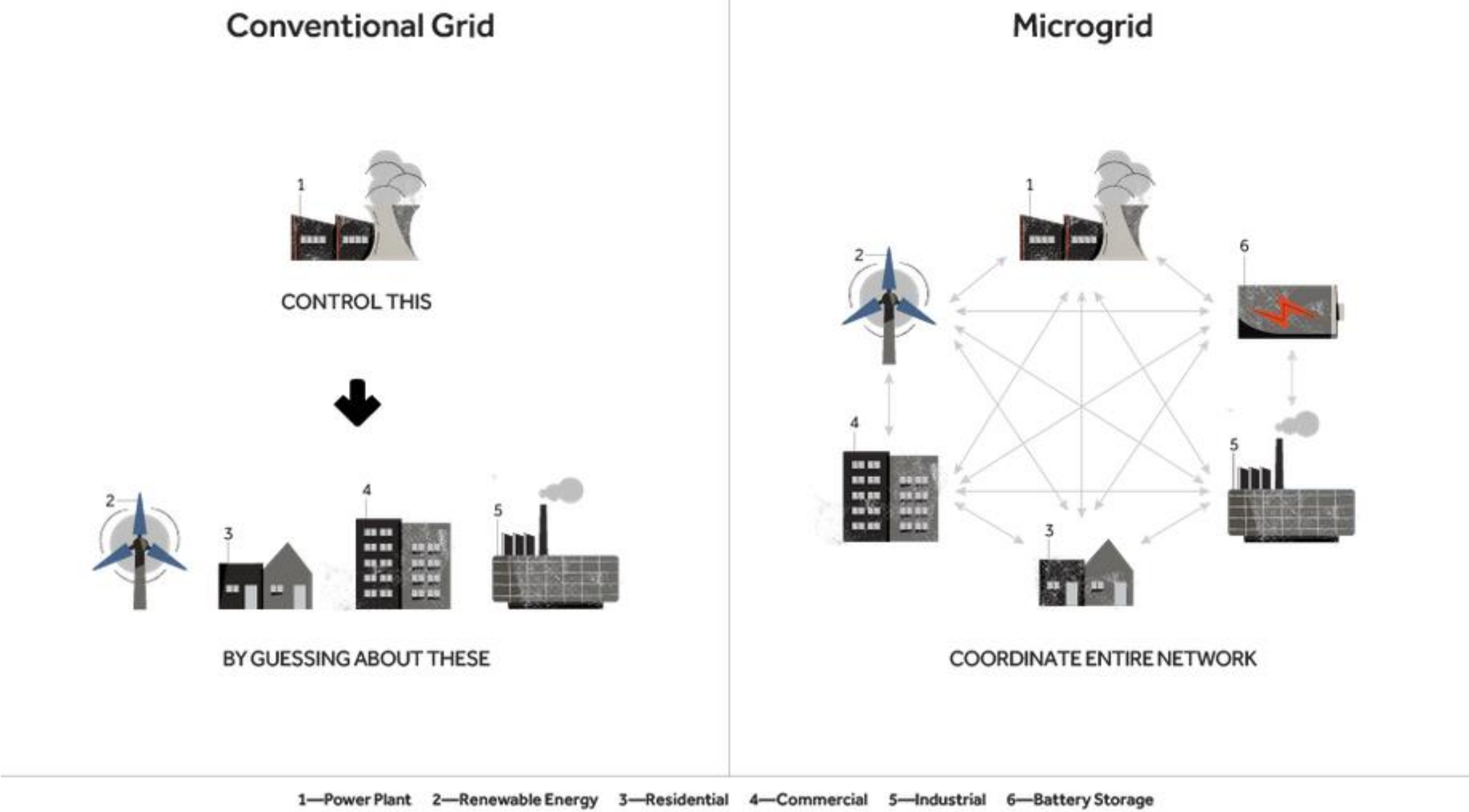
- It is connected to both the local generating units and the utility grid thus preventing power outages.

- Excess power can be sold to the utility grid or can store in storage system.

- Size of the microgrid may range from housing estate(few kW) to municipal regions(few MW).

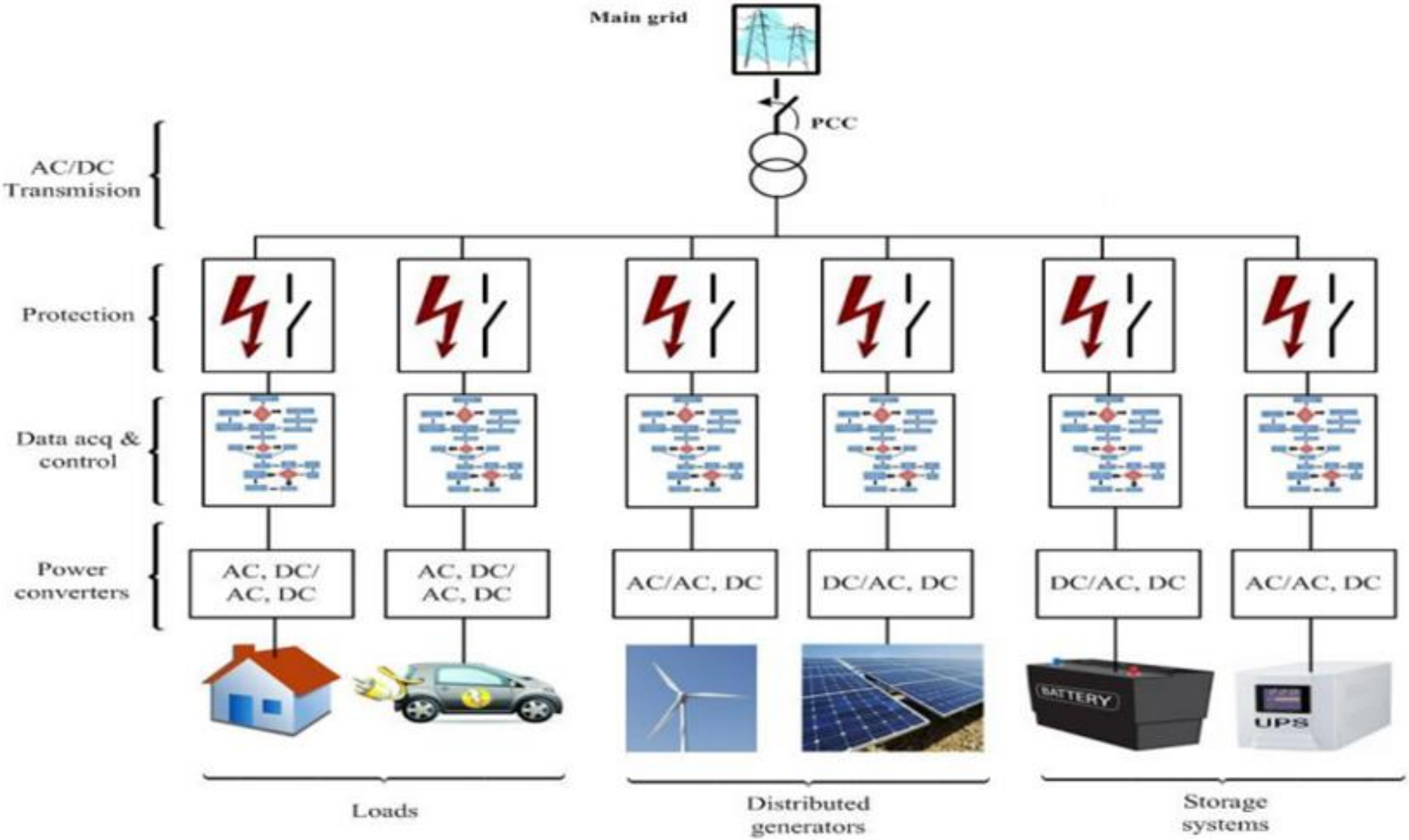
What is a Microgrid?

Legacy Bulk Electrical System ⇨ Microgrids



That Was Then… **…This is Now**

Microgrid Architecture



Component of Microgrid

1.Distributed Generations:

The classification of microgrid generation technologies has given below

- Renewable/Inverter based distribution generations (solar thermal, photovoltaic PV, wind, fuel cell, CHP, hydro, biomass, biogas etc.)

- Non-renewable/Inertia based distribution generations (diesel engine, steam turbine, natural gas generator, induction and synchronous generators etc).

Component of Microgrid

2. Energy Storage Device :

The classification of microgrid storage technologies has given below

- Electrochemical systems (Embracing batteries and flow cells such as Li-ion, Zn-bromide)

- Kinetic energy storage systems (Flywheel energy storage)

- Potential energy storage (Pumped hydro or compressed air storage)

Component of Microgrid

3. Load:

- Resistive load such as household load
- Inductive load for instance Industrial Load
- Sensitive or critical load such as data center, electronic load
- And demand high-level reliability Load for example Hospital
- Sheddable & Unsheddable Load

Challenges of Utility Grid

Today power industry faces many problems including rising cost of energy, power quality and stability, aging infrastructure, mass electrification, climate change and so on.

Microgrid generally represent three goals of society

- Reliability(Physical, Cyber)
- Sustainability(Carbon foot print)
- Economic(Cost optimizing, Efficiency)

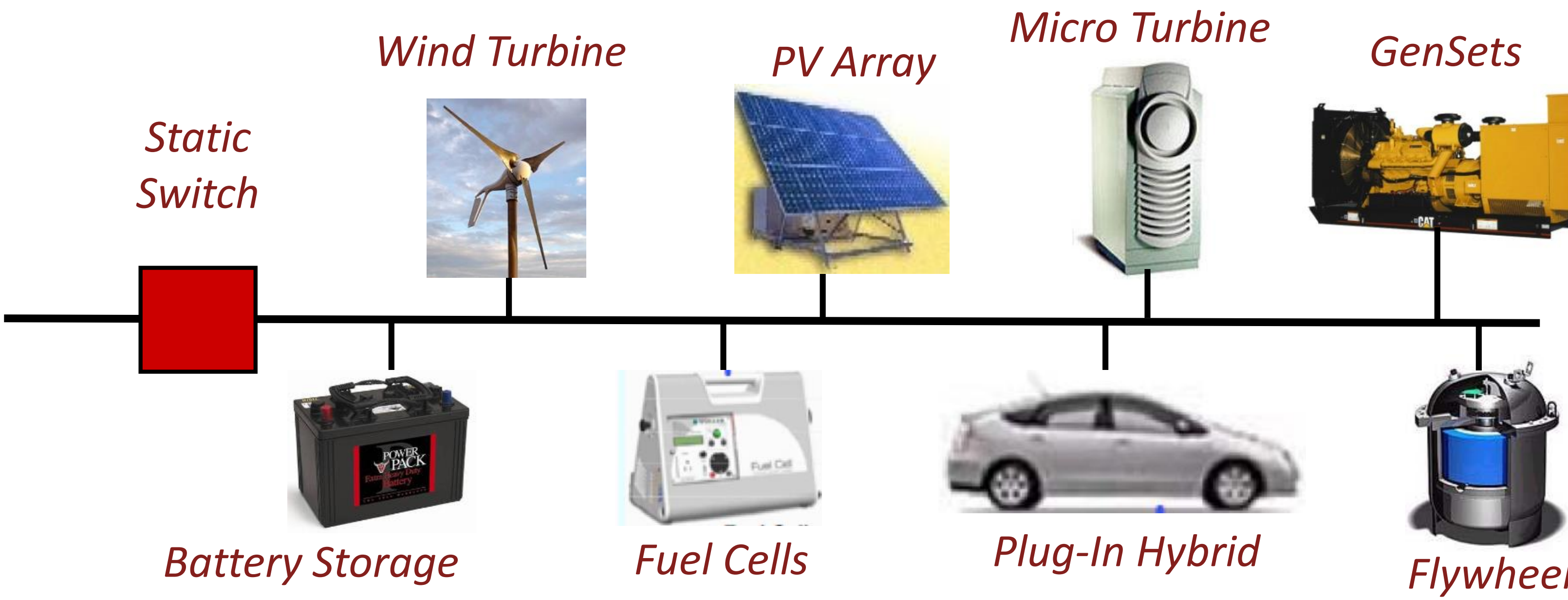
Application of Microgrid

Couple of special application of microgrid, in the regions of underdeveloped transmission infrastructure, for example

- Remote villages
- Islands

Microgrid helps to reduce transmission losses significantly.

Microgrid Importance



- Microgrids provide the most promising means of integrating large amounts of distributed sources into the power grid
- Particularly important for renewable energy sources
- Microgrids can provide higher reliability, energy security and surety, and open the door to significant system efficiency improvements using Combined Heating & Power (CHP)

The control operation of microgrid is required

- To add or subtract new micro-sources without any modification of present component in the system

- For selecting or optimising operation point of microgrid autonomously as well as manually

- To connect or to isolate microgrid from the grid immediately and smoothly when demanded

- For controlling active and reactive power independently.

- For the correction of voltage sag and system imbalances.

- To meet the load dynamics involvement of grid

Features required to achieve flexibility of microgrid

- The microgrid should capable to follow voltage ride-through standard of that particular area.
- It is very important to have black-start quality if system needs to restart for natural disaster or maintenance purpose.
- Microgrid needs to estimate grid impedance prior to connected or disconnect with it.
- The most important feature gives microgrid better control is a storage energy management and a comprehensive control system.

Requirement for ESSs in Microgrids

- Microgrids range in generating capacity from kW's to MW's and provide power to a variety of users ranging from small cell phone towers to large commercial, industrial and military customers.

- Energy storage is used to enhance the stability and efficiency of microgrids by decoupling the generation source from the load.

Requirement for ESSs in Microgrids

- This is particularly useful for systems with diesel generation or intermittent renewables as the means of electricity production.

- Each microgrid is a unique response to a customer need. Whether energy storage is incorporated in a system is a strong function of the microgrid systems integrator, the customers' technological sophistication, and budget.

Requirement for ESSs in Microgrids

- Sizing of a suitable battery bank in terms of power and energy help in shaving the peak demand.

- The ESS stores excess renewable energy and supply load when renewable energy is low.

- When ESS discharges its energy to power grid its generating positive real power.

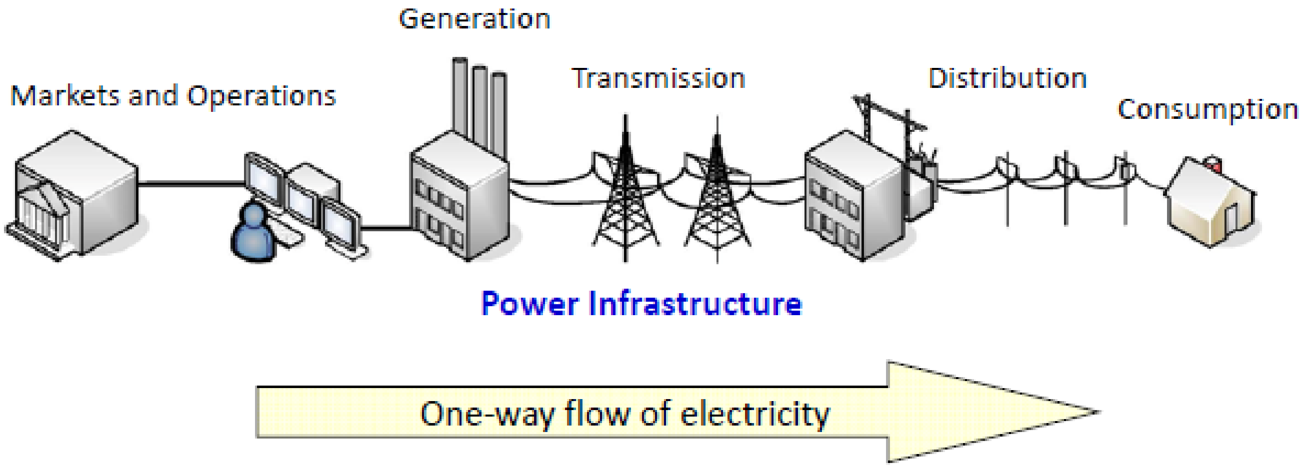
Classification of Microgrid

Based on microgrid application, we can classified microgrid into

Classification of Microgrid								
Classification	Integrated Level	Utilities' Impact	Responsibility	Application Area	Operational Mode	Geographically Span	Power Quality	Remarks
Facility Microgrid	Middle level	Little impact on utilities	For complement mostly for vital systems	Mainly found in North America specially for Industry/Institution application where technology is matured	intentional or unintentional island Mode	2 miles	High	Making great use of renewable energy, increasing energy efficiency, reducing pollution, greenhouse gas emissions & high power quality reliability for sensitive loads as well to single business-entity
Remote Microgrid	Low level	No impact on utilities	Independent system for isolated electrification	Mainly found in distant areas, Islands, developing countries etc	Islanded Mode only	30 miles	Relaxed	Mostly decentralized control & maximum power use is limited for the customers
Utility Microgrid	High level	Massive impact on utilities	For support of power systems	Mainly found in Japan, Europe, China where renewable energy is rapidly developing	Grid tie Mode	15 miles	Medium	Providing high power quality & reliability to sensitive local loads, contributing to utility stability & robustness as well

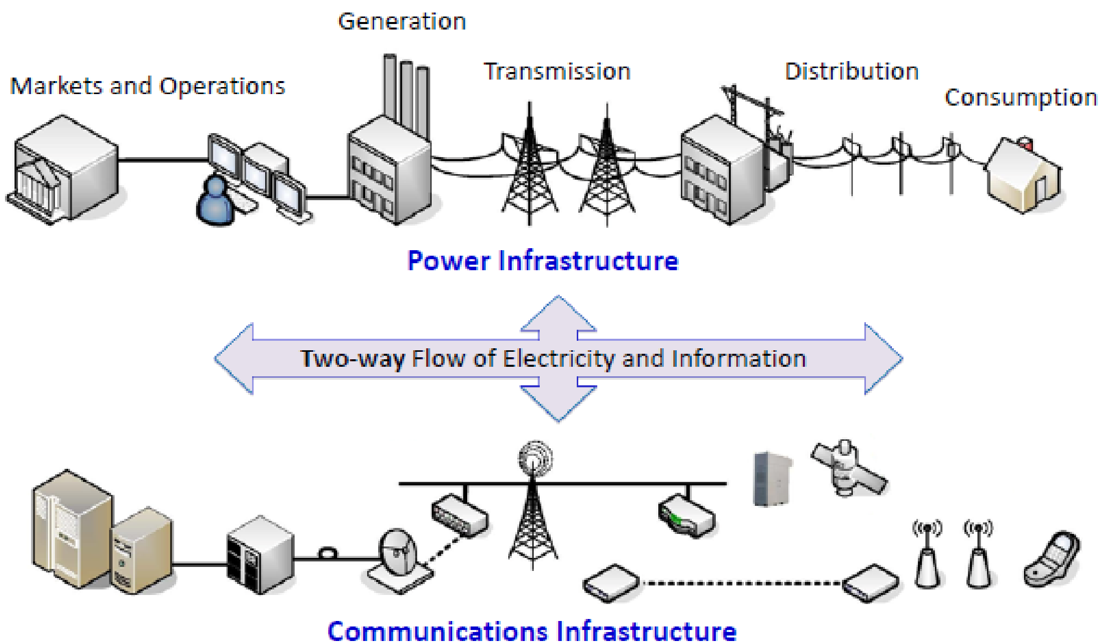
Communication needs

- However, distributed structure of this system including fuel cells, photovoltaic systems, wind turbines, micro turbines, synchronous generators and energy storage elements arises the problem how the measurement and control information receive and transmit between the control center and the field elements.



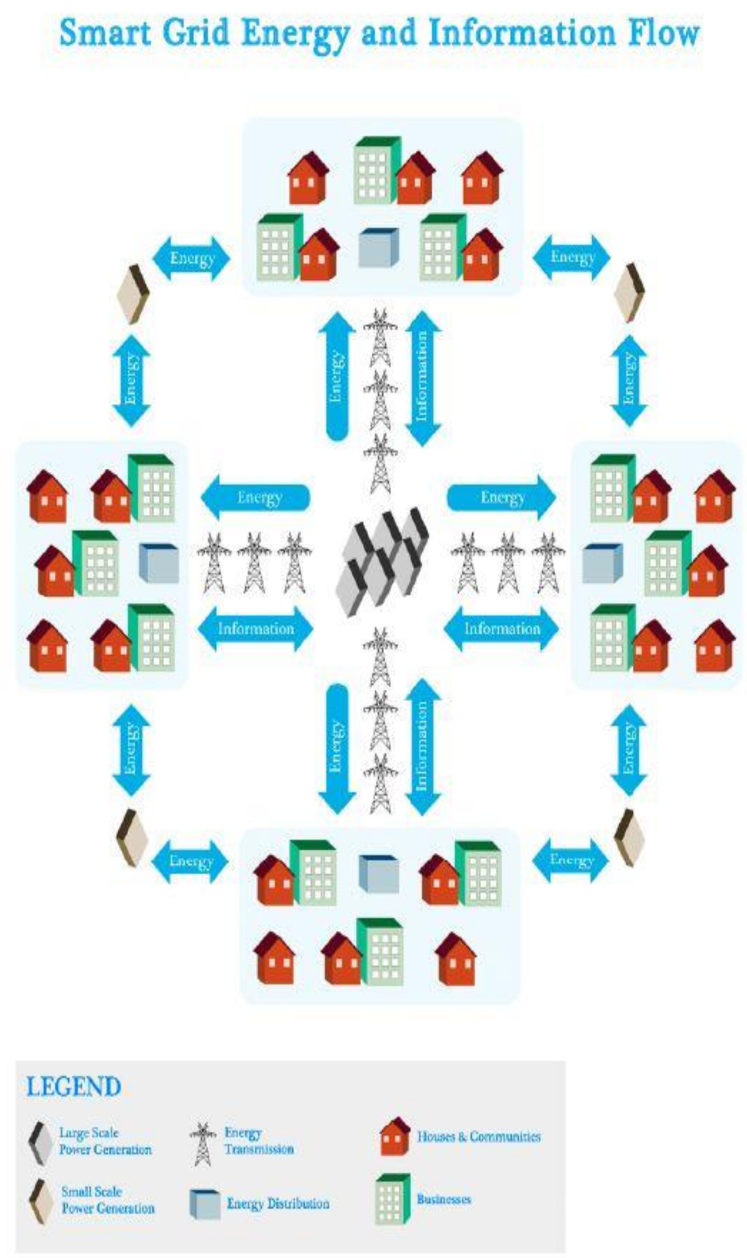
Communication needs

- Since the SCADA system developed for centralized and decentralized system has not this type of ability, a communication and automation networks need to be established.



Smart grid

- Smart grid is a relatively new approach for the future power system that integrates **electricity** and **communication** on power system network which supplies digital information on the real time network operation for the operator and consumers.

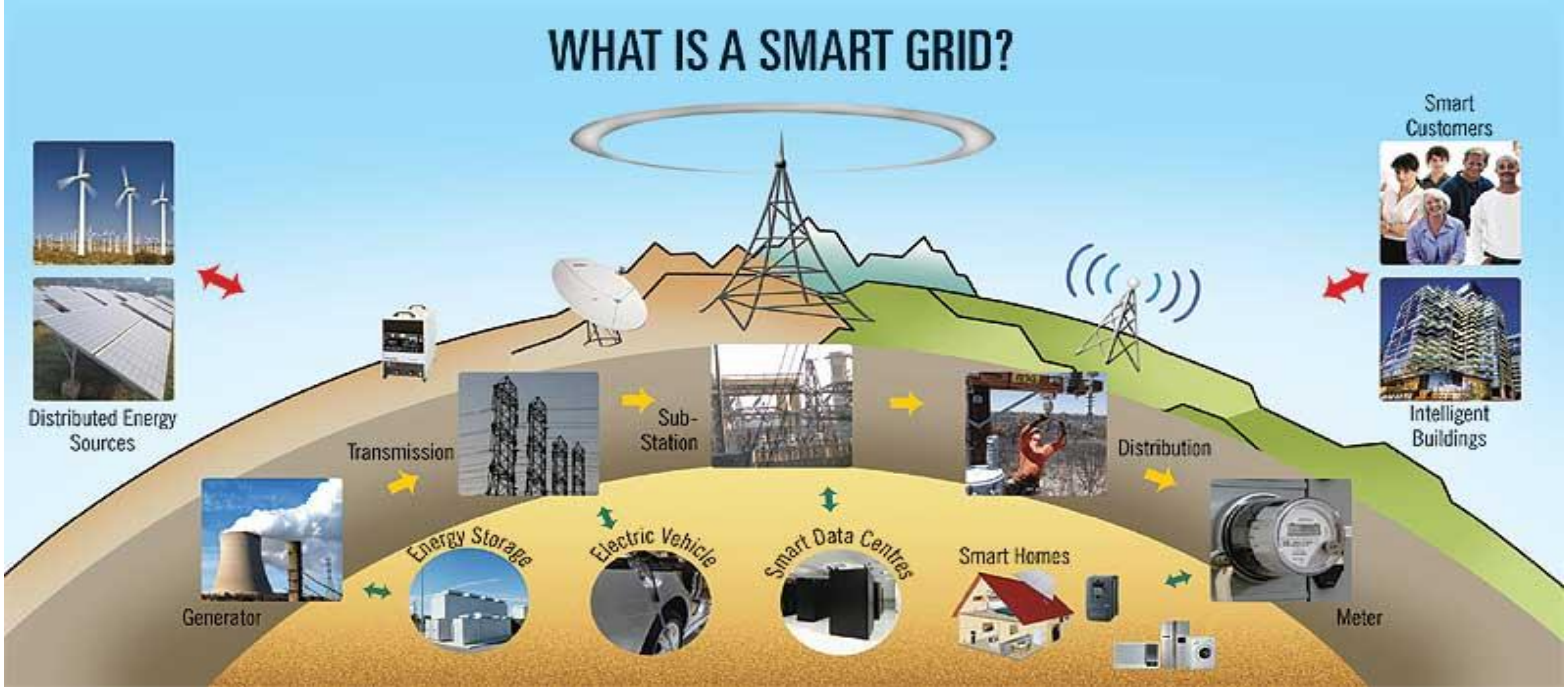


Smart grid

- Additionally, advanced control methods, digital sensing and metering, advanced grid devices are a few of the major technologies involved in the implementation of smart grid.

Smart grid

- Smart grid technology broadens power knowledge and involves interdisciplinary research area such as: communication, automation, sensor and control.



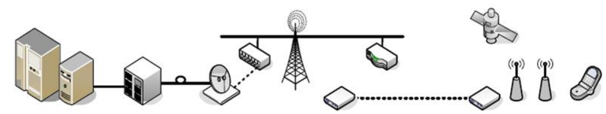
Expectations

Our demands…

… more information.

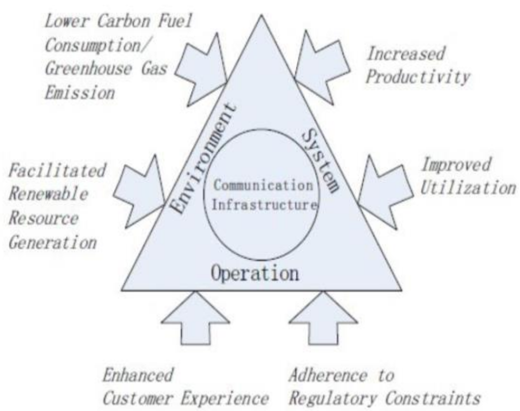
… secure energy generation from different sources.

… managing the grid by using novel technologies



… lower CO2 footprint !

… flexibility to easily adaptive new regulations



… a response to solve the ever increasing grid complexity

Smart Grid Definitions

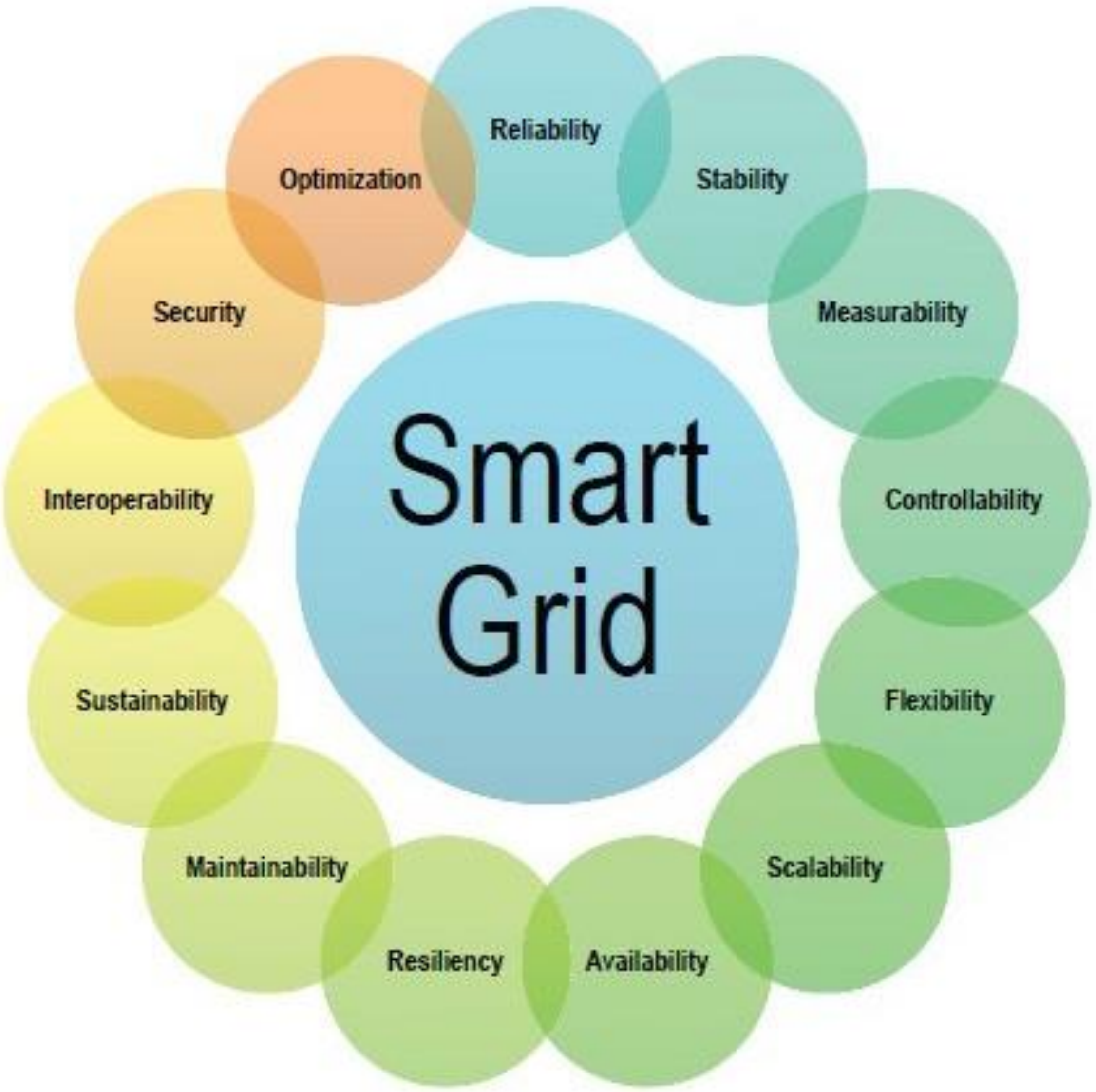
USA DoE

a. Self-healing from power disturbance events
b. Enabling active participation by consumers in demand response
c. Operating resiliently against physical and cyber attack
d. Providing power quality for 21st century needs
e. Accommodating all generation and storage options
f. Enabling new products, services, and markets
g. Optimizing assets and operating efficiently

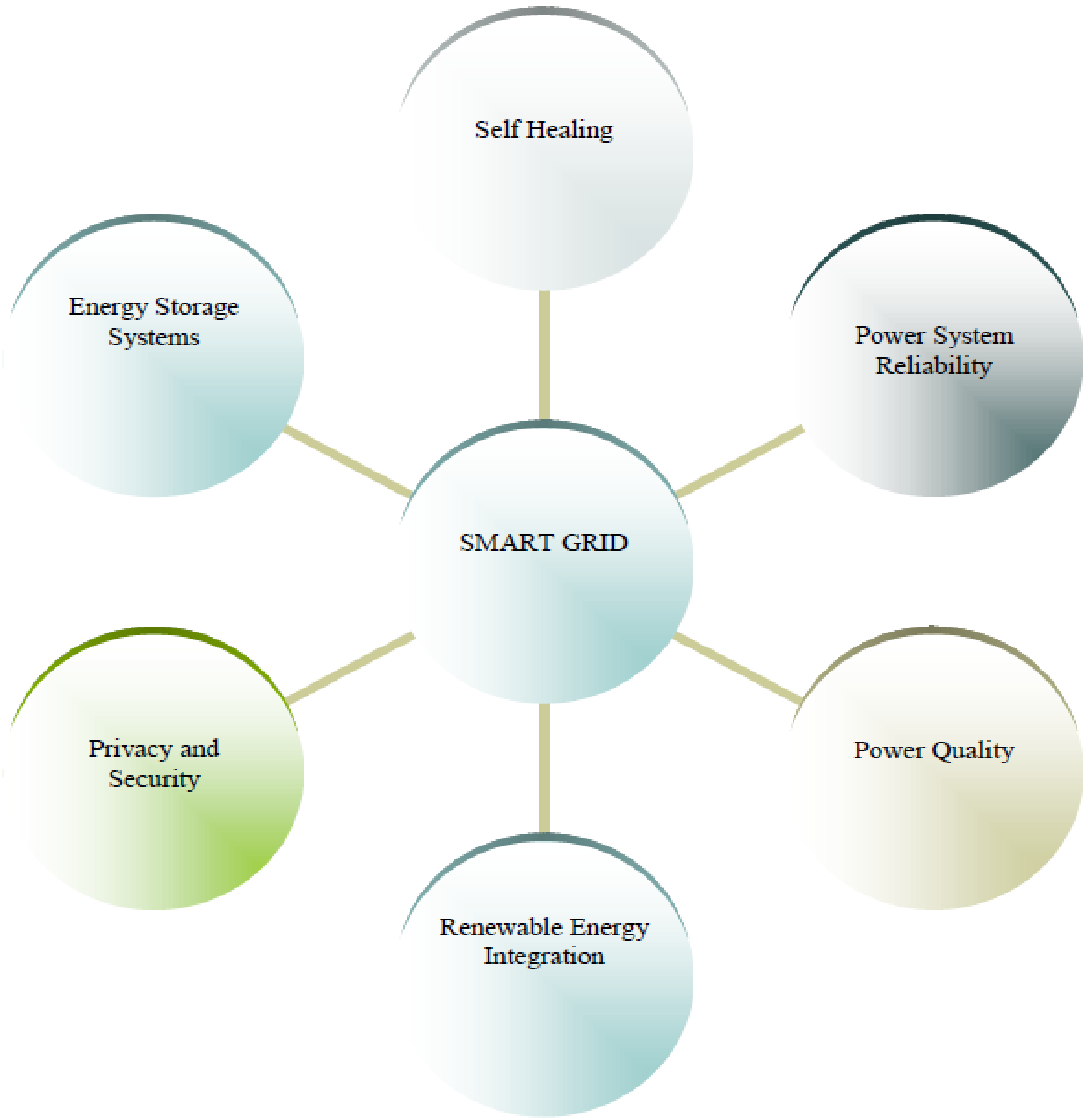
EU JRC Smart Grid Group

a. Allows integration of any type and any scale generation sources to to the grid
b. Allows the consumers to participate optimization of system operation,
c. Provides further information to end-users about how to use the sources,
d. Decreases the defective effects of electrical chain on environment,
e. Provides to improve transmission security and energy quality of current state,
f. Increases the quality of service,
g. Supports to construct complete European market,

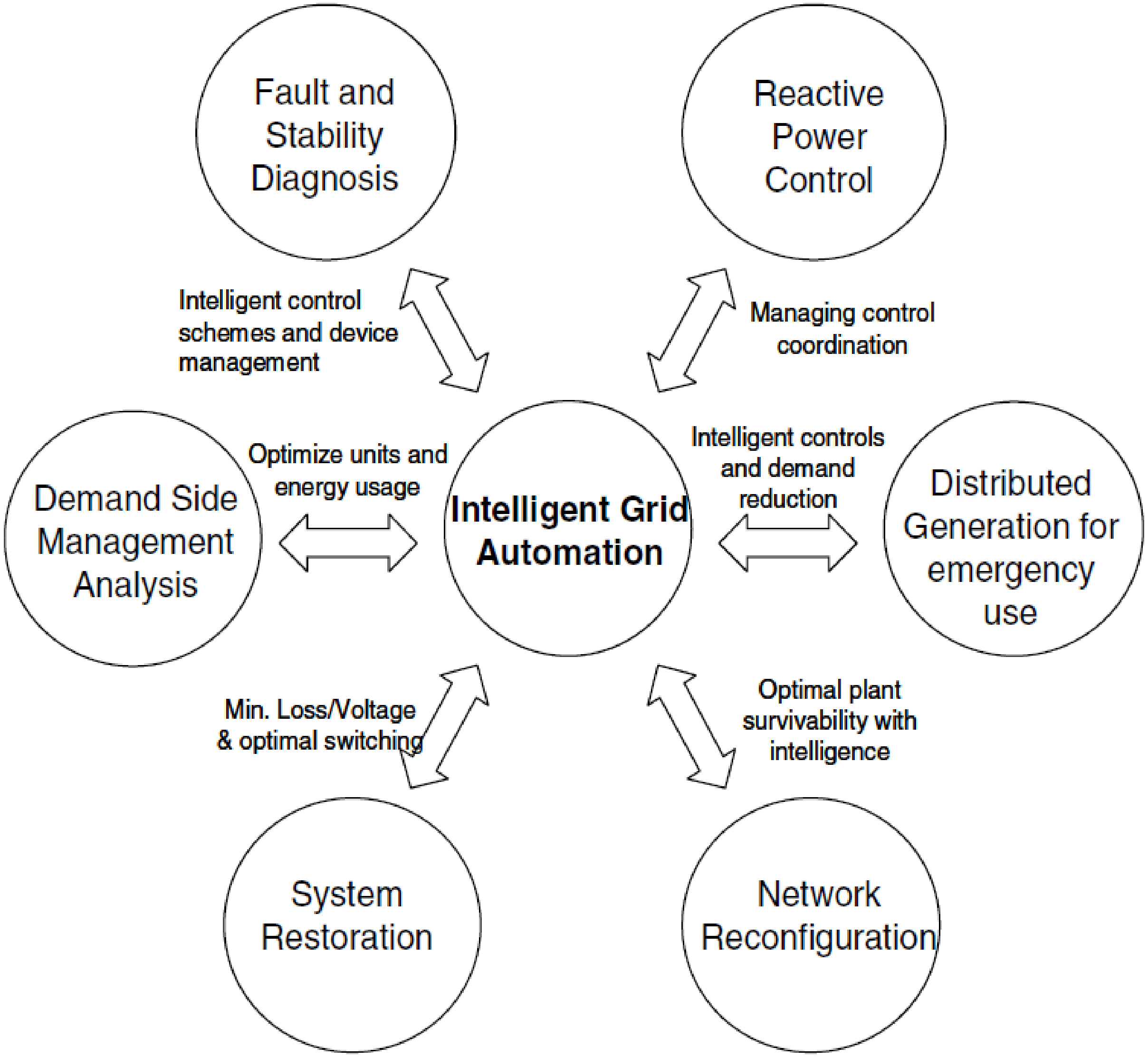
Requirements of Smart Grids



Key Functions of Smart Grid

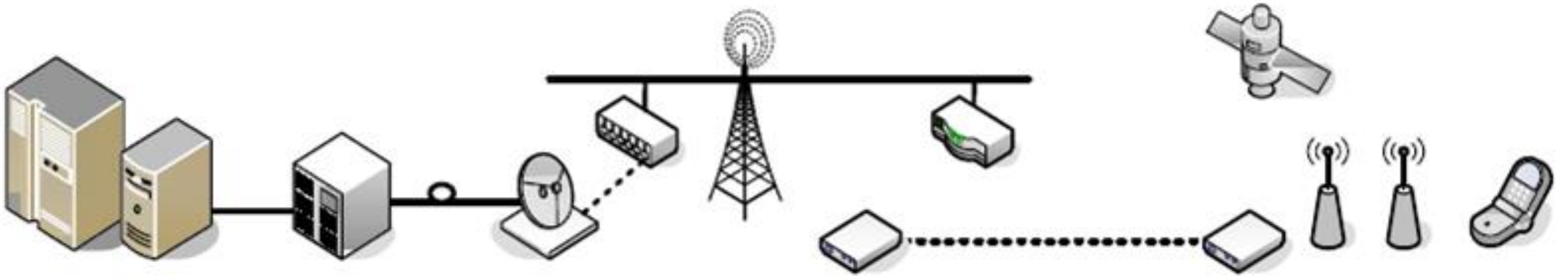


Smart Grid intelligent automation functions



Communication Methods in Smart Grids

- Several different communication methods can be used in smart grids from generation to consumers.



Communication Methods in Smart Grids

Data transmission methods are mainly used as;

- mobile computers,
- mobile phones,
- additional hardware of computers,
- remote monitoring and periodic measuring.

They are used in many fields such as

- vehicle tracking
- the remote control of automated devices,
- machines or systems
- smart home applications

Communication Methods in Smart Grids

Technology	Spectrum	Data Rate	Coverage Range	Applications	Limitations
GSM	900-1800 MHz	Up to 14.4 Kpbs	1-10 km	AMI, Demand Response, HAN	Low date rates
GPRS	900-1800 MHz	Up to 170 kbps	1-10 km	AMI, Demand Response, HAN	Low data rates
3G	1.92-1.98 GHz 2.11-2.17 GHz (licensed)	384 Kbps-2 Mbps	1-10 km	AMI, Demand Response, HAN	Costly spectrum fees
WiMAX	2.5 GHz, 3.5 GHz, 5.8 GHz	Up to 75 Mbps	10-50 km (LOS) 1-5 km (NLOS)	AMI, Demand Response	Not widespread
PLC	1-30 MHz	2-3 Mbps	1-3 km	AMI, Fraud Detection	Harsh, noisy channel environment
ZigBee	2.4 GHz-868-915 MHz	250 Kbps	30-50 m	AMI, HAN	Low data rate, short range

Anticipated Smart Grid Benefits

- According to the National Inst. of Standards and Technology (NIST):

  - 1. Improving Power Reliability and Quality
    - Better monitoring using sensor networks and communications
    - Better and faster balancing of supply and demand

  - 2. Minimizing the Need to Construct Back-up (Peak Load) Power Plants
    - Better demand side management
    - The use of advanced metering infrastructures

- According to the National Inst. of Standards and Technology (NIST):
  - 3. Enhancing the capacity and efficiency of existing electric grid
    - Better monitoring using sensor networks and communications
    - Consequently, better control and resource management in real-time
  - 4. Improving Resilience to Disruption and Being Self-Healing
    - Better monitoring using sensor networks and communications
    - Distributed grid management and control

- According to the National Inst. of Standards and Technology (NIST):
  - 5. Expanding Deployment of Renewable and Distributed Energy Sources
    - Better monitoring using sensor networks and communications
    - Consequently, better control and resource management in real-time
    - Better demand side Management
    - Better renewable energy forecasting models
    - Providing the infrastructure / incentives

- According to the National Inst. of Standards and Technology (NIST):
  - 6. Automating maintenance and operation
    - Better monitoring using sensor networks and communications
    - Distributed grid management and control
  - 7. Reducing greenhouse gas emissions
    - Supporting / encouraging the use of electric vehicles
    - Renewable power generation with low carbon footprint

- According to the National Inst. of Standards and Technology (NIST):

  - 8. Reducing oil consumption
    - Supporting / encouraging the use of electric vehicles
    - Renewable power generation with low carbon footprint
    - Better demand side Management (Q: Why?)

  - 9. Enabling transition to plug-in electric vehicles
    - Can also provide new storage opportunities

- According to the National Inst. of Standards and Technology (NIST):
  - 10. Increasing consumer choice
    - The use of advanced metering infrastructures
    - Home automation
    - Energy smart appliances
    - Better demand side Management

Advanced Metering Infrastructure (AMI) Example

- AMI Project in Lubbock, TX
  - South Plains Electric Cooperative AMI Project
  - Started in 1996
  - To talk back and forth with utilities
  - Report outages and electric usage
  - 34,285 smart meters already connected (75%)
  - Targeting 100% by 2014!

Smart Meter

Customer System (CS) Example

- Peak Energy Agriculture Rewards (PEAR) in Fresno, CA
  - Demand response program for agriculture customers
  - Cell phone / web-to-wireless remote control.

Customer System (CS) Example

- Peak Energy Agriculture Rewards (PEAR) in Fresno, CA
  - Controls:
    - On/off switches
    - Pump pressure and flow
    - Air temperature
    - Soil moisture, etc.

  - Monthly cash payments for “negawatt” in peak demand
  - PEAR is registered demand response “aggregator”.

Equipment Manufacturing (EM) Example

- Whirlpool Corporation Smart Grid Project, Benton Harbor, MI
  - Manufacturing of smart residential
  - Communicating over a home network, Internet, and AMI
  - Will allow consumers to defer or schedule their energy use
    - Clothes dryers, dishwashers, and refrigerators
    - Has user-interface to program appliances
  - Smart Dryer: http://www.youtube.com/watch?v=fISKjaFRh3Q

Integrated System (IS) Example

- Golden Spread Electric Cooperative Project in Amarilo, TX
  - SCADA Communication for Better Reliability & Outage Management
    - Both wireless and power line carrier communications systems
  - Automated Distribution Circuit Switches
  - Automated Capacitors
  - Automated Regulators
  - Circuit Monitors/Indicators
  - Smart Meters, Programmable Communicating Thermostats, DLC

Distribution System (DS) Example

- SGIG Distribution Automation Project, Atlantic City, NJ
  - Wireless Mesh Networking with Fiber Optic Connectivity
    - Access Points
    - Mesh Repeaters
  - Automation
    - Monitoring
    - Control / Switching

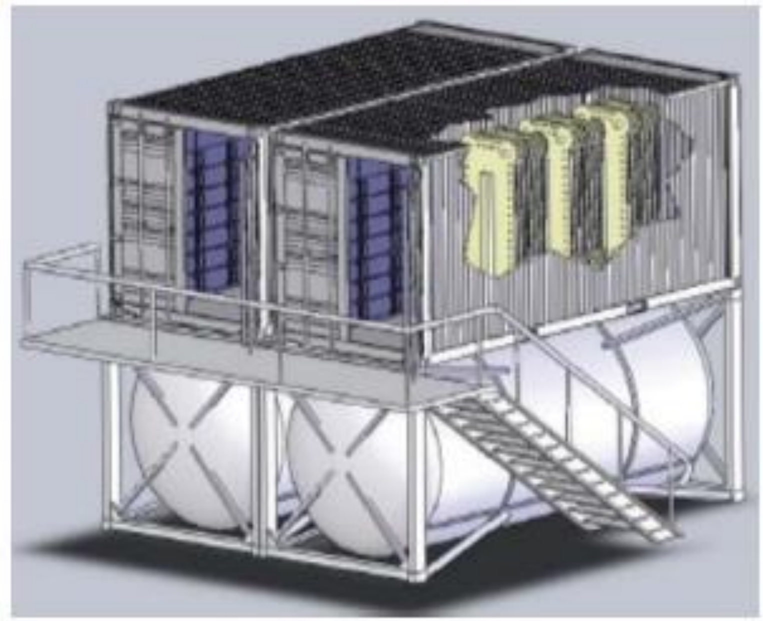
Wireless Mesh Network

Transmission Systems (TS) Example

- Midwest Energy Inc. Smart Grid Project, Hays, KS
  - Nine Relay-based Phasor Measurement Units (PMUs)
  - Synchrophasor Communications Network
  - Advanced transmission applications for synchrophasors:
    - Angle and frequency monitoring
    - Post-mortem analysis (disturbances and system failures)
    - Voltage and voltage stability monitoring
    - Improved state estimation
    - Steady-state benchmarking

Storage Demonstration (SD) Example

- Ktech Corp: Battery for Renewable Energy Integration
  - California's Central Valley
  - Batteries: 250 kW, 1 MWh
  - 180 kW Photovoltaic Farm
  - Store the energy generated
  - Dispatch power to:
    - Run an irrigation pump
    - Inject energy back into the grid during peak times



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Questions&Answers

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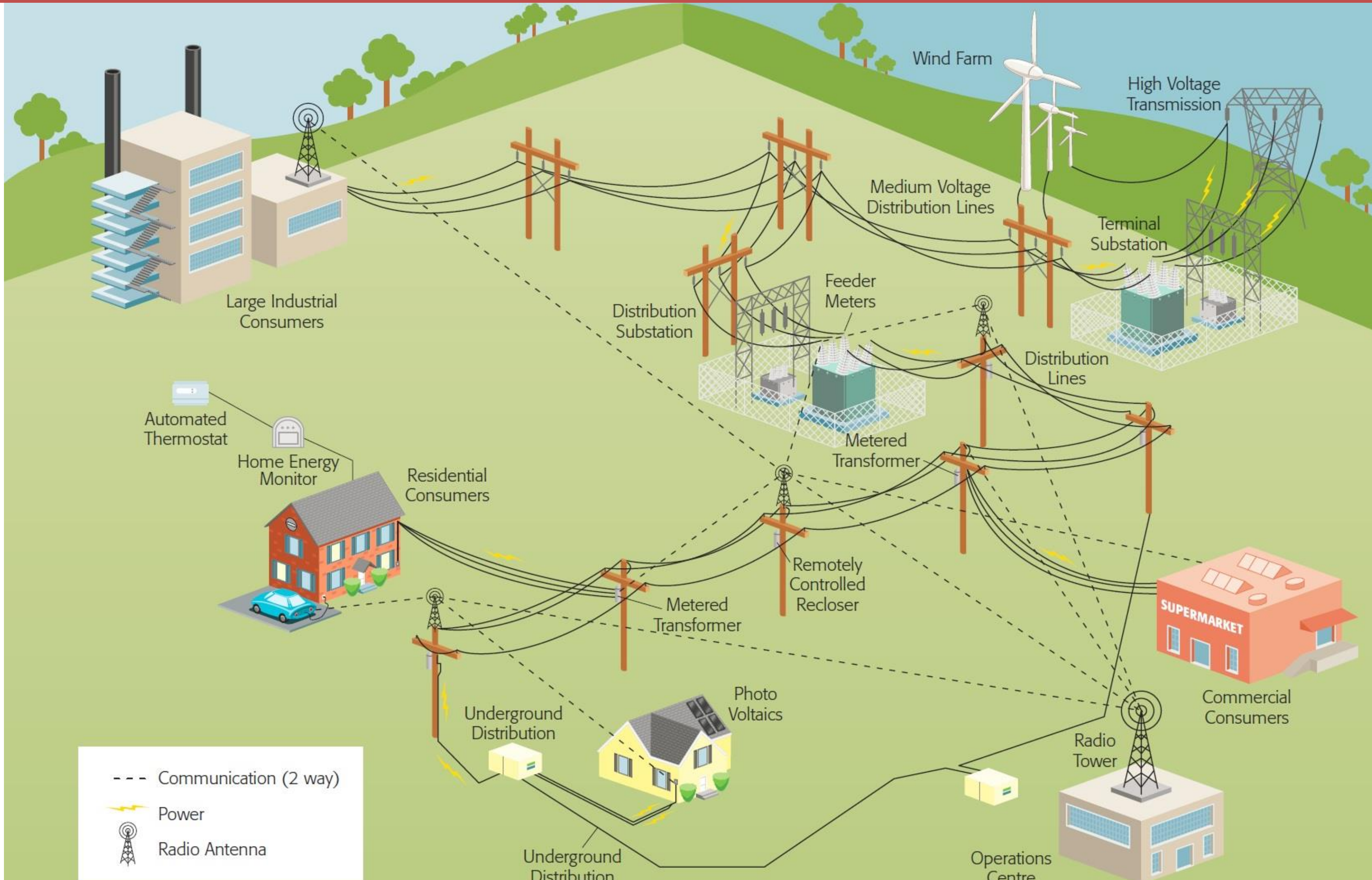

Questions&Answers