Introduction to Smart Grid

Grid

- ✓ The term grid is used for an electrical system that may support all or some of the following four operations: ***electricity generation, electricity transmission, electricity distribution, and electricity control***.

What Makes a Grid "Smart?"

- ✓ In short, the **digital technology** that allows for two-way communication between the utility and its customers, and the **sensing** along the transmission lines is what makes the grid smart.
- ✓ Like the Internet, the Smart Grid will consist of controls, computers, automation, and new technologies and equipment working together, but **in this case, these technologies will work with the electrical grid to respond digitally to our quickly changing electric demand.**

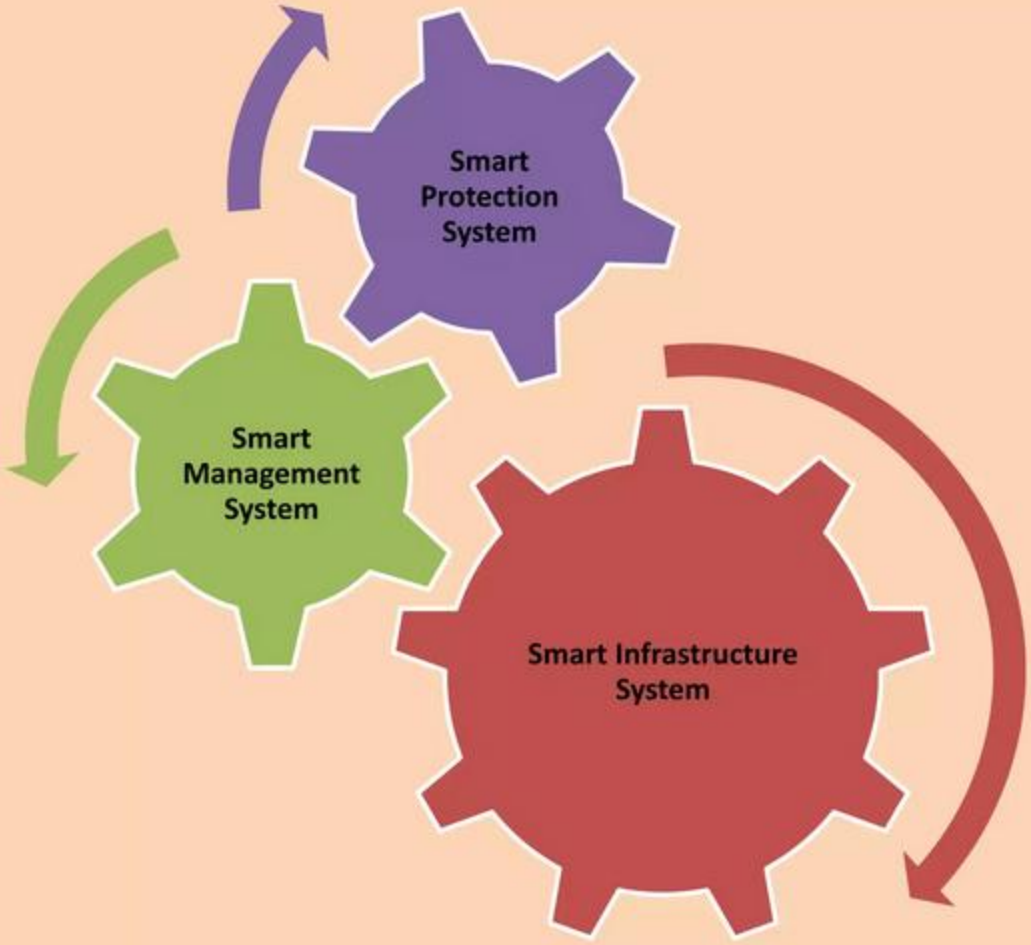
Smart Grid

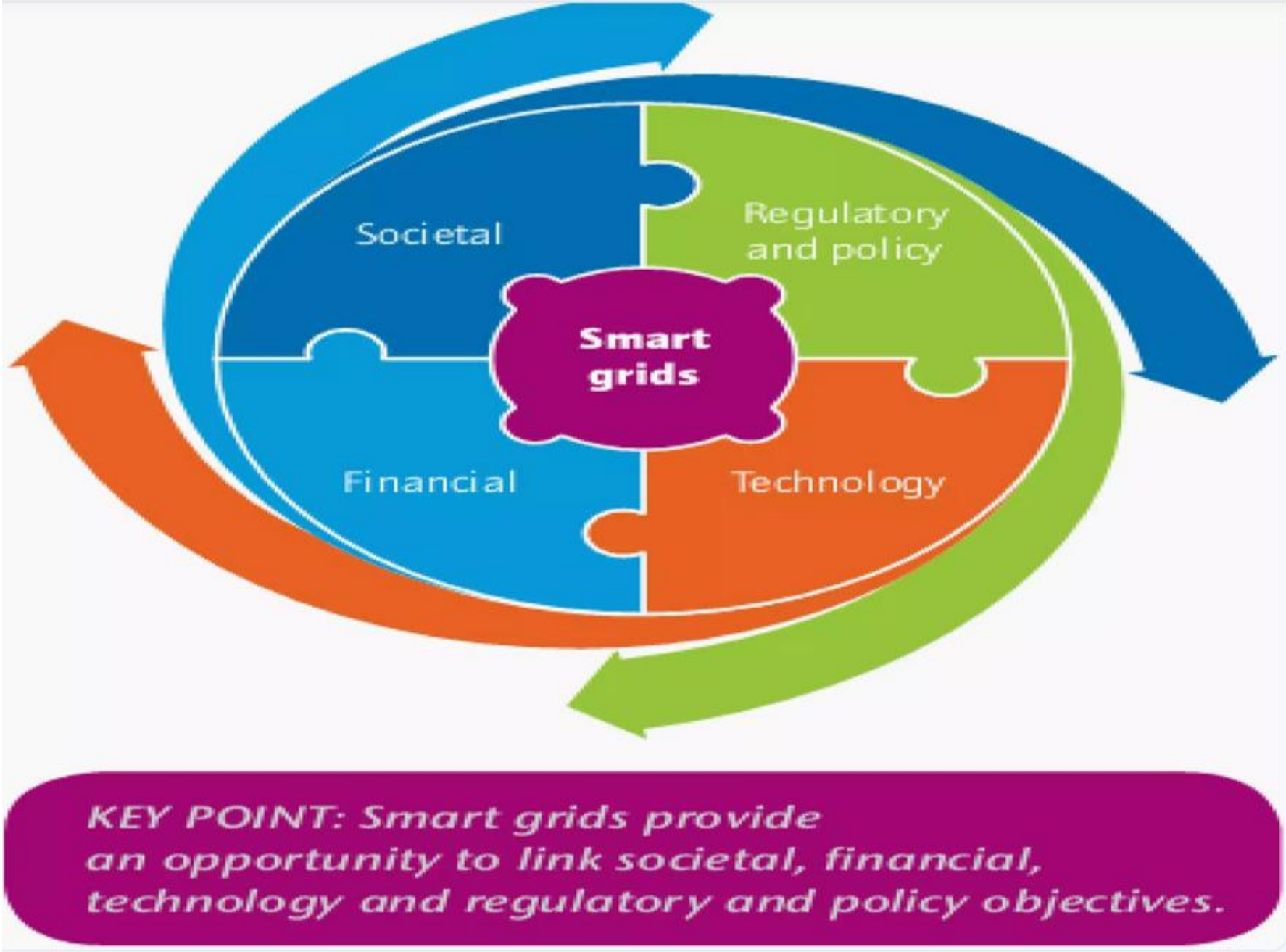
- ✓ Smart Grid ***facilitates efficient and reliable end-to-end intelligent two-way delivery system*** from source to sink through ***integration of renewable energy sources, smart transmission and distribution***.
- ✓ In this way Smart Grid technology shall ***bring efficiency and sustainability*** in meeting the growing electricity demand with ***reliability and best of the quality.***
- ✓ Smart Grid also ***enables real time monitoring and control of power system*** as well as ***helps in reduction of AT&C losses, demand response and demand side management, power quality management, outage management, smart home energy system etc.***

Continue...

- ✓ Smart Grid will ***act as a backbone infrastructure to enable new business models like smart city, electric vehicles, smart communities*** apart from more resilient and efficient energy system and tariff structures.
- ✓ A smart grid also called smart electrical/power grid, intelligent grid, future grid, inter-grid, or intra-grid, is an enhancement of the 20th century power grid.
- ✓ ***More specifically, the SG can be regarded as an electric system that uses information, two-way, cyber-secure communication technologies, and computational intelligence in an integrated fashion across electricity generation, transmission, substations, distribution and communications to achieve a system that is clean, safe, secure, reliable, resilient, efficient, and sustainable.***

Three major systems in Smart Grid from a Technical Prospective





KEY POINT: Smart grids provide an opportunity to link societal, financial, technology and regulatory and policy objectives.


Financial Firms (commodity training)
Independent System Operators
Manufacturers and Vendors
Regulatory Bodies (Market monitoring)
SMART GRİD
STAKE HOLDERS
R & D Organizations
Environmental Protection Agencies
Consumers
Electric Utilities

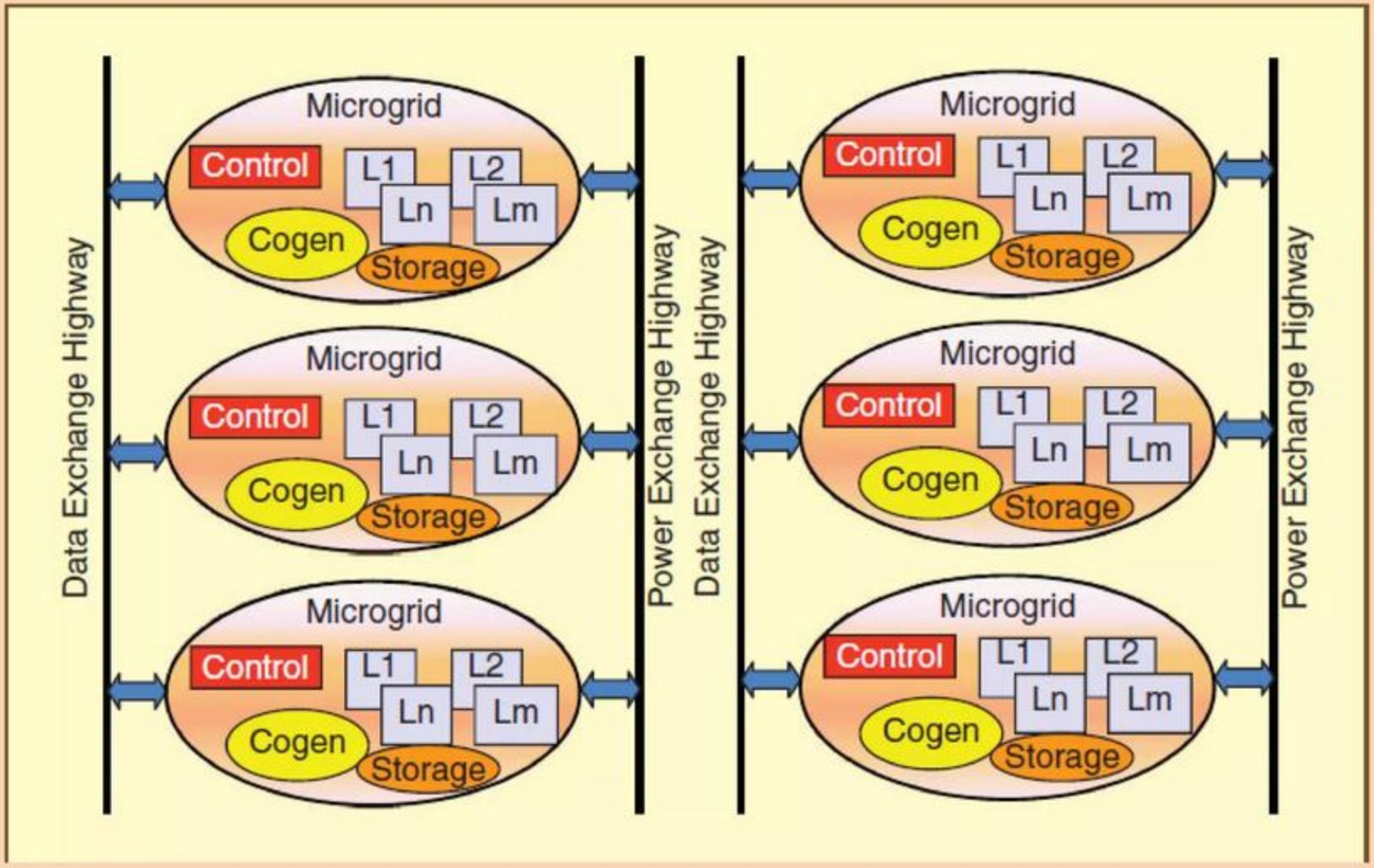
Aims of the Smart Grids-The Vision

- ✓ Provide a user centric approach and allow new services to enter into the market
- ✓ Establish innovation as an economical driver for the electricity networks renewal
- ✓ Maintain security of supply, ensure integration and interoperability
- ✓ Provides accessibility to a liberalised market and foster competition
- ✓ Enables distributed generation and utilization of renewable energy sources
- ✓ Ensure best use of central generation
- ✓ Consider appropriately the impact of environmental limitations
- ✓ Enable demand side participation (DSR, DSM)
- ✓ Inform the political and regulatory aspects
- ✓ Consider the societal aspects

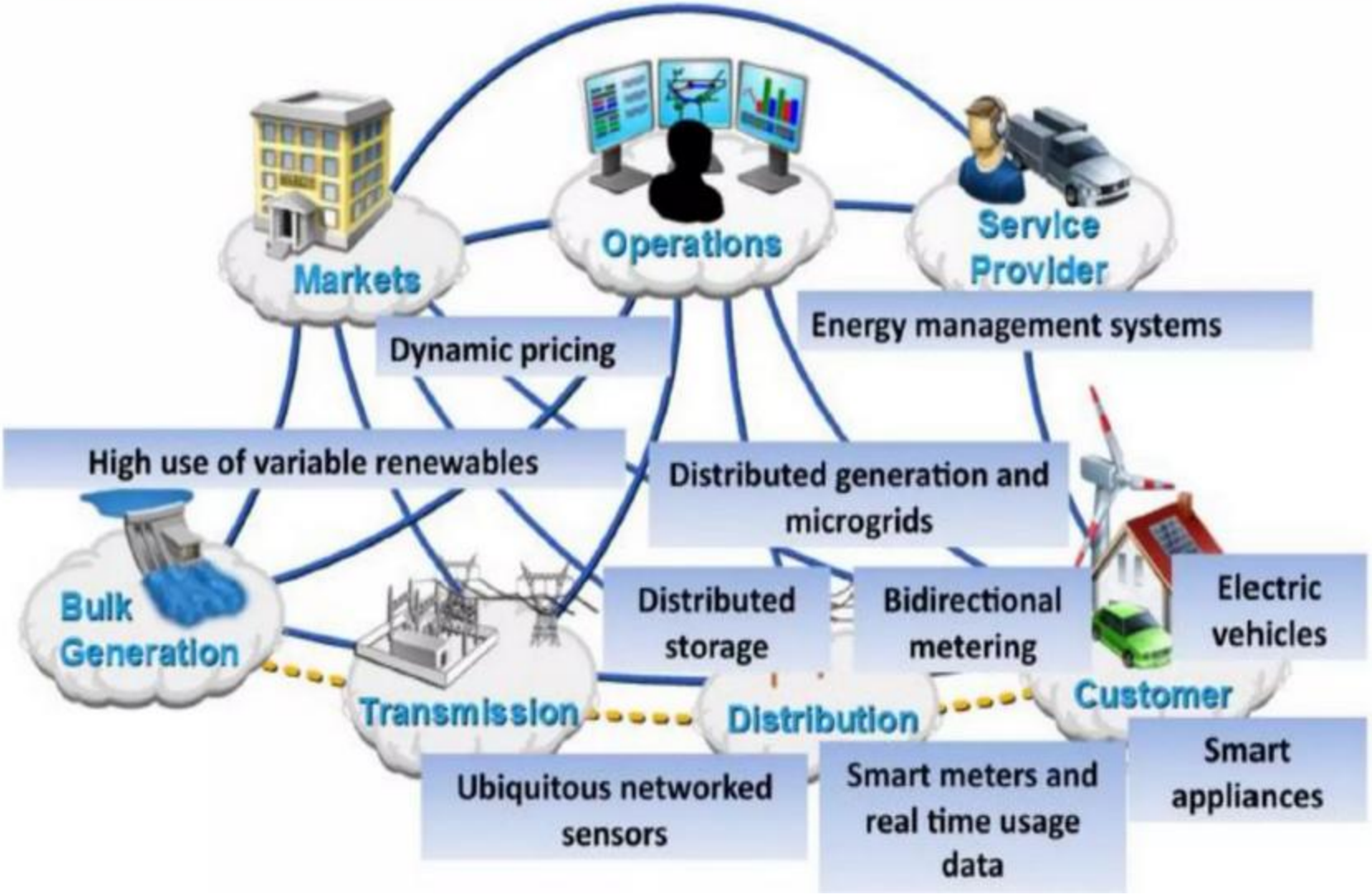
Smart Grid Drivers

- ✓ Increase in electricity demand and supply shortfall
- ✓ Loss reduction
- ✓ Increase in unit cost of electricity
- ✓ Managing human element
- ✓ Reliability
- ✓ Efficiency
- ✓ Renewable energy integration
- ✓ Grid improvement
- ✓ Technological advances

Future Smart Grid

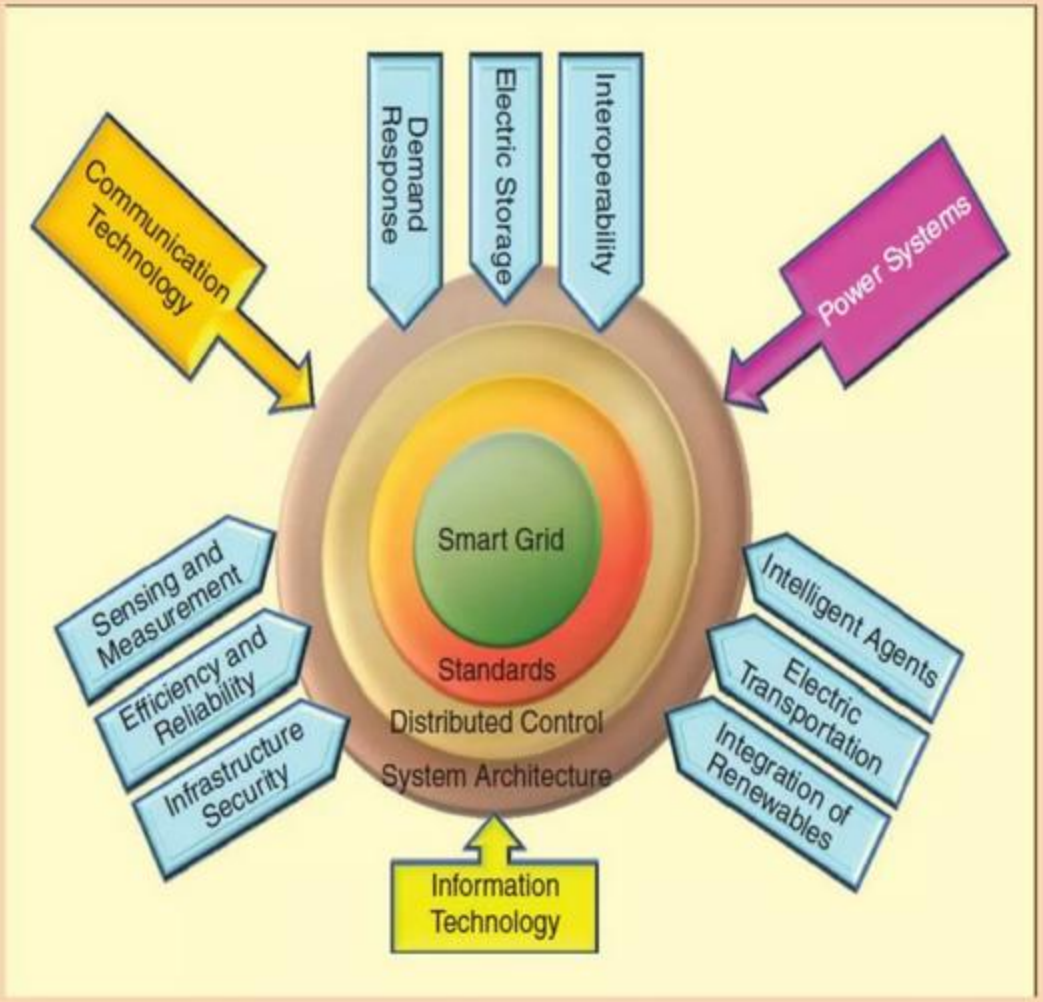


Conceptual Model of the Smart Grid



Smart Grid Components

- ✓ Intelligent appliances
- ✓ Smart power meters
- ✓ Smart sub-stations
- ✓ Smart distribution
- ✓ Smart generation
- ✓ Universal access to affordable, low carbon electrical power generation



Seven Key Characteristics of Smart Grid

- ✓ Enables active participation by consumers
- ✓ Accommodates all generation and storage options
- ✓ Enables new products, services and markets
- ✓ Provides power quality for the digital economy
- ✓ Optimizes asset utilization and operates efficiently
- ✓ Anticipates and responds to system disturbances (Self-heals)
- ✓ Operates resiliently against attack and natural disaster

Modern Hardware for Smart Grid

Group Name	Technology
✓ Power Electronics Devices	✓ Unified Power Flow Controller (UPFC) ✓ DVAR or DSTATCOM ✓ Static Voltage Regulator (SVR) ✓ Static VAR Compensator (SVC) ✓ Solid State Transfer Switch ✓ Dynamic Break ✓ AC/DC Inverter

Continue...

Group Name	Technology
✓ Superconductivity	✓ First Generation Wire ✓ HTS Cable ✓ Second Generation Wire ✓ Micro Turbine
✓ Distributed Generation	✓ Fuel Cell ✓ PV ✓ Wind Turbine

Continue...

Group Name	Technology
✓ Distributed Storage	✓ NAS Battery ✓ Vanadium Redox Battery (VRB) ✓ Ultra-capacitors ✓ Superconducting Magnetics Energy Storage (SMES)
✓ Composite Conductors	✓ Aluminium Conductor Composite Core Cable (ACCC Cable) ✓ Aluminium Conductor Composite Reinforced Cable (ACCRC Cable) ✓ Annealed aluminium, steel supported (AASS)

Smart Grid Technologies: Wide area monitoring and control

- ✓ **Hardware:** Phasor measurement units (PMU) and other sensor equipment
- ✓ **Systems and Software:**
  1. Supervisory control and data acquisition (SCADA),
  2. wide area monitoring systems (WAMS),
  3. wide area adaptive protection, control and automation (WAAPCA),
  4. wide area situational awareness (WASA).
- ✓ **Implementation area:** Generation and Transmission

Smart Grid Technologies: Information and Communication Technology

✓ **Hardware:**

1. Communication equipment (Power line carrier, WIMAX, LTE, RF mesh network, cellular)
2. Routers
3. Relays and switches
4. Gateway
5. Computers (Servers)

✓ **Systems and Software:**

1. Enterprise resource planning software (ERP)
2. Customer information system (CIS)

✓**Implementation area:**

Generation, Transmission, Distribution, Industrial, Service, Residential

Smart Grid Technologies: Renewable and Distributed Generation Integration

- ✓ **Hardware:**
  1. Power conditioning equipment for bulk power and grid support
  2. Communication and control hardware for generation and enabling storage technology
- ✓ **Systems and Software:**
  1. Energy management system (EMS)
  2. Distribution management system (DMS)
  3. SCADA
  4. Geographic information system (GIS)
- ✓ **Implementation area:** Generation, Transmission, Distribution, Industrial, Service, Residential

Smart Grid Technologies: Transmission Enhancement

- ✓ **Hardware:**
  1. Superconductors
  2. FACTS
  3. HVDC
- ✓ **Systems and Software:**
  1. Network stability analysis
  2. Automatic recovery systems
- ✓ **Implementation area:** Transmission

Smart Grid Technologies: Distribution Grid Management

✓ **Hardware:**

1. Automated re-closers
2. Switches and capacitors
3. Remote controlled distribution generation and storage
4. Transformer sensors
5. Wire and cable sensors

✓ **Systems and Software:**

1. Geographical information system (GIS)
2. Distribution management systems (DMS)
3. Outage management systems (OMS)
4. Workforce management system (WMS)

✓ **Implementation area:** Distribution

Smart Grid Technologies: Advanced Metering Infrastructure

- ✓ **Hardware:**
  1. Smart meter
  2. In-home displays
  3. Servers
  4. Relays
- ✓ **Systems and Software:** Meter data management system (MDMS)
- ✓ **Implementation area:** Distribution, Industrial, Service, Residential

Smart Grid Technologies: Electric Vehicle Charging Infrastructure

- ✓ **Hardware:**
  1. Charging infrastructure,
  2. Batteries
  3. Inverters
- ✓ **Systems and Software:**
  1. Energy billing
  2. Smart grid-to-vehicle charging (G2V) and discharging vehicle-to-grid (V2G) methodologies
- ✓ **Implementation area:** Distribution, Industrial, Service, Residential

Smart Grid Technologies: Customer Side Systems

✓ **Hardware:**

1. Smart appliances
2. Routers
3. In-home display
4. Building automation systems
5. Thermal accumulators
6. Smart thermostat

✓ **Systems and Software:**

1. Energy dashboards
2. Energy management systems
3. Energy applications for smart phones and tablets

✓**Implementation area:** Industrial, Service, Residential

Smart Grid Benefits

- ✓ Self-healing
- ✓ Motivates and includes the consumers
- ✓ Resists attack
- ✓ Provides power quality for 21st century needs
- ✓ Accommodates all generation and storage options
- ✓ Enables markets, market participation
- ✓ Optimizes assets and operates efficiently

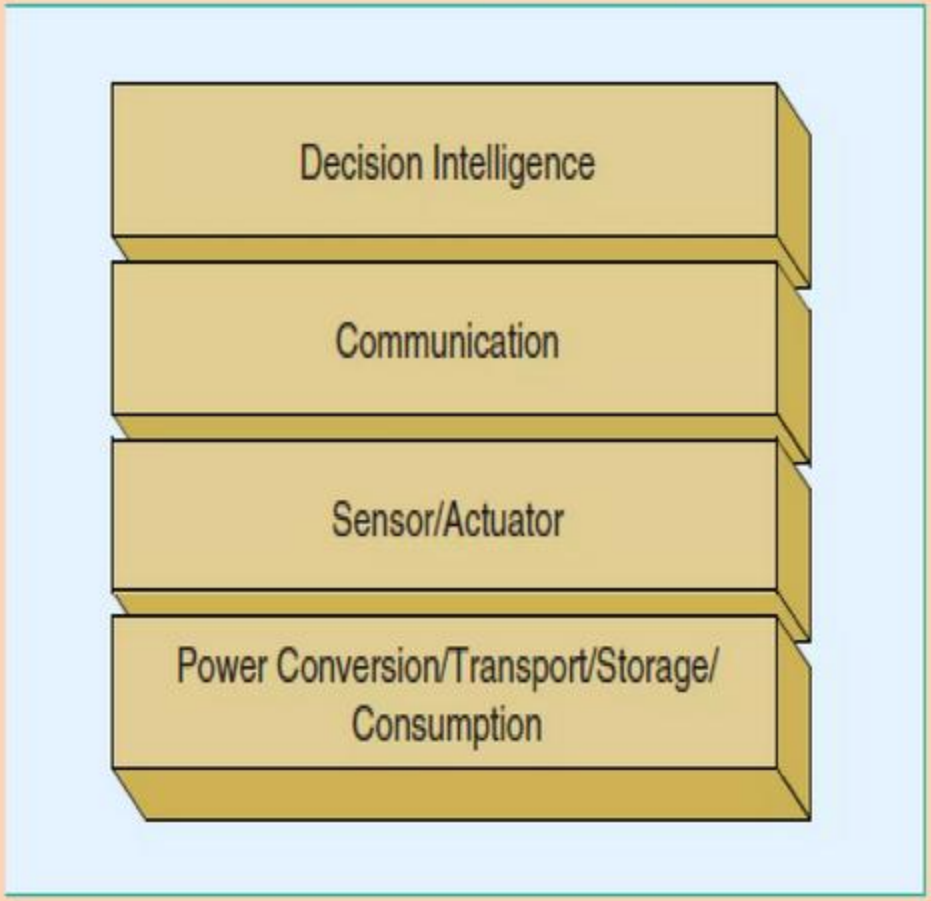
Smart Grid Challenges

- ✓ Financial resources (high capital investment)
- ✓ Government support
- ✓ Compatible equipment
- ✓ Speed of technology development
- ✓ Policy and regulation
- ✓ Cooperation
- ✓ Integration of CIS, GIS, OMS
- ✓ Standardisation

Traditional Grid V/S Smart Grid

1. Electromechanical	1. Digital
2. One-way communication	2. Two-way communication
3. Centralised power generation	3. Distributed power generation
4. A smaller number of sensors	4. Full Grid sensor layout
5. Manual monitoring	5. Automatic monitoring
6. Manual recovery	6. Automatic recovery
7. Failures and power outages	7. Adaptive and islanded
8. Few user options	8. More user options
9. Hierarchical	9. Network
10. Limited control	10. Pervasive control
11. Few customer choice	11. Many customer choice

Four Technology Layers of Smart Grid



The analogy can be drawn between these layers with the human body.

- ✓ The bottom layer is analogous to the body's muscles
- ✓ The sensor/actuator layer corresponds to the body's sense organs
- ✓ The communication layer corresponds to the nerves
- ✓ The decision intelligence layer corresponds to the human brain

Functions to perform

- ✓ Microgrid control and scheduling (demand response and efficiency)
- ✓ Intrusion detection and countermeasures (cyber security)
- ✓ Equipment monitoring and diagnostic systems (asset management)
- ✓ Wide area monitoring protection and control
- ✓ Online system event identification and alarming (safety and reliability)
- ✓ Power oscillation monitoring and damping (stability)
- ✓ Voltage and VAR optimization (energy efficiency and demand reduction)
- ✓ Voltage collapse vulnerability detection (security)
- ✓ Autonomous outage detection and restoration (self healing)
- ✓ Intelligent load balancing and feeder reconfiguration (energy efficiency)

Continue...

- ✓ Self-setting and adaptive relays (protection)
- ✓ End-user energy management systems (consumer participation, efficiency)
- ✓ Dynamic power compensation, using energy storage and voltage source inverters (efficiency and stability)