Challenges in Smart Grid Implementation

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- **What is Smart Grid?**
- **Is the present grid not smart?**
- **Why Smart Grid?**
- **Smart or Intelligent ???**

Growth of Electricity Sector

- The electric power system is more than 130 years old.
- Formation of interconnected transmission grids for optimal utilization of the generation resources.
- The size and complexity of the system have been growing.
  - A.C. transmission systems are being planned at 1100/1200 kV.
  - Generating unit sizes have gone upto 800/1000 MW.
  - HVDC links (+/- 500/800 kV) are in operation for back to back and long distance power transfer.
- The power system in India consists of about 255GW of installed generation capacity.
  - In US, it is about 1100 GW.
  - Both have millions of circuit km of transmission and distribution networks.

- Operating concerns:
  - Maintaining security, reliability, quality, stability of power system with Economic Operation
  - Ensuring better customer focus and cheaper electricity cost.

- Computer aided monitoring & dispatching system is required.
  - On line monitoring, operation and control of the present day power systems.
  - Energy Management System (SCADA based) and Distribution Automation System (DAS) in place.
  - Synchrophasor based Wide Area Monitoring System being deployed for real time visualization and control of the system,

Some of the Recent Concerns

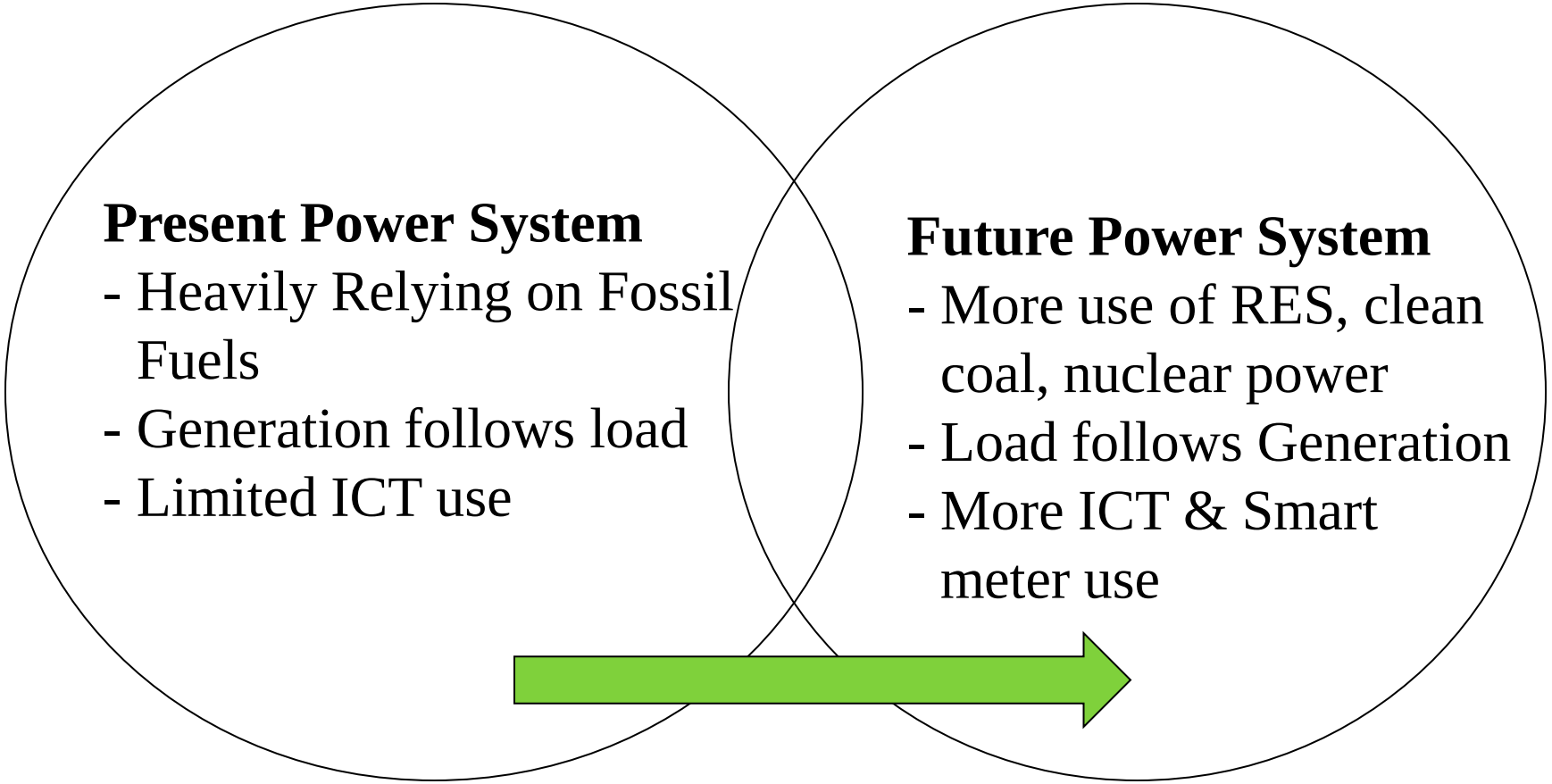
- Limited expansion of transmission network as compared to the generation addition.
  - Most of the generation, T&D systems have become old.
- Increased transmission and distribution losses.
- Lack of dynamic data for health monitoring and control.
- Increased concern towards vulnerability and resilience of the system under natural and man made disasters.
- Growing environmental concerns including the global warming.
- Poor power quality, limited customer focus and their participation in energy Management.
- Meeting the ever increasing electricity demand.

Key Drivers to Technological Changes in the Electricity Sector

- **Development of New Materials - Polymeric, Composite, Nano, Superconducting materials.**
- **Use of Alternate and Renewable Energy Sources to address Global Environmental Concerns**
- **Development of New Devices and Technologies**

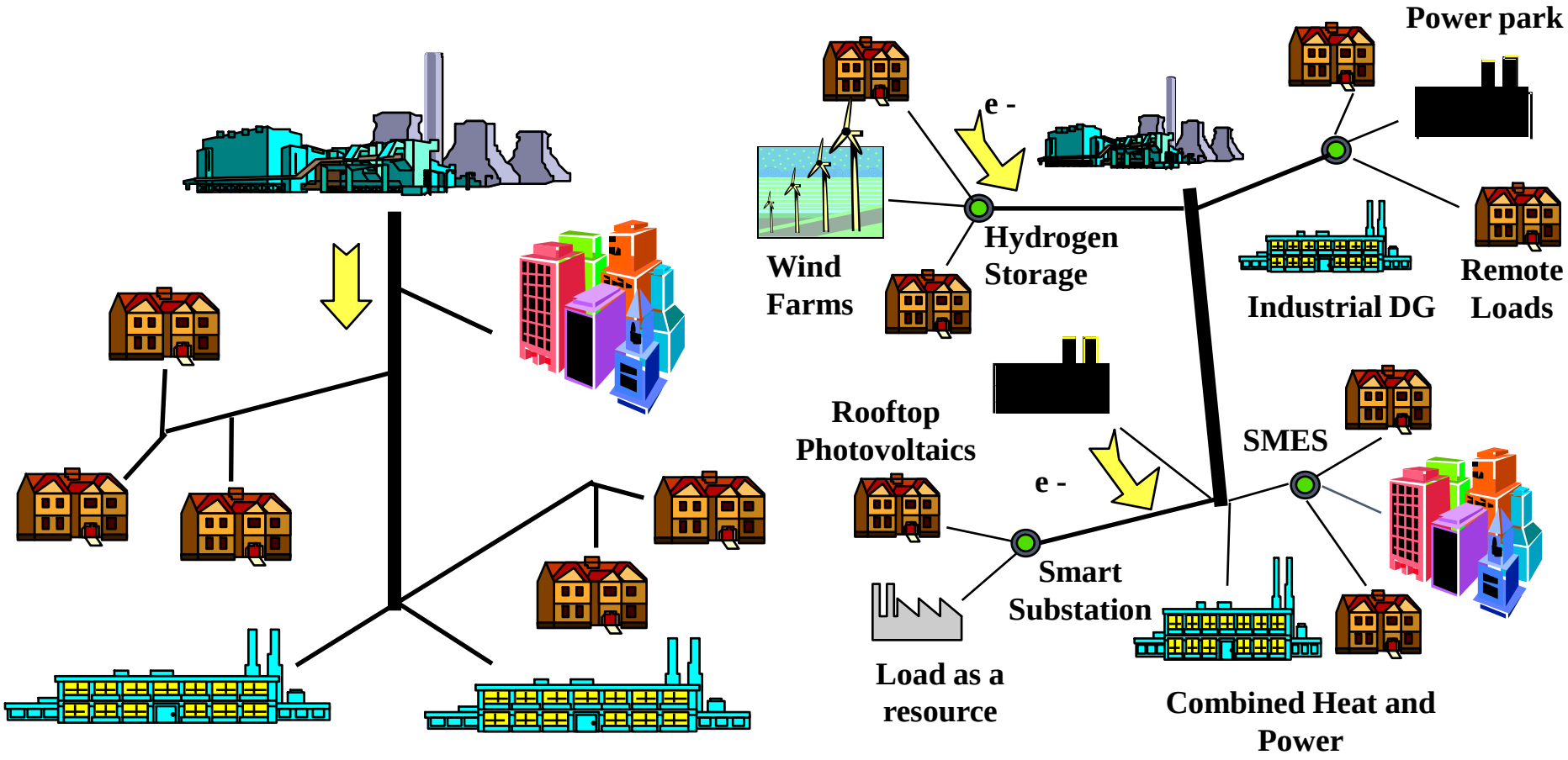
  - Power Electronic Devices, DSP, Sensors, Information & Communication Technology
- **Maintaining Security, Reliability and Resilience of Large Interconnected System**
- **Maintaining Quality of Supply and IT Enabled Services in Distribution Sector**
- **Regulatory Changes in the Electricity Sector**

Present and Future Power System



Today's Electricity …

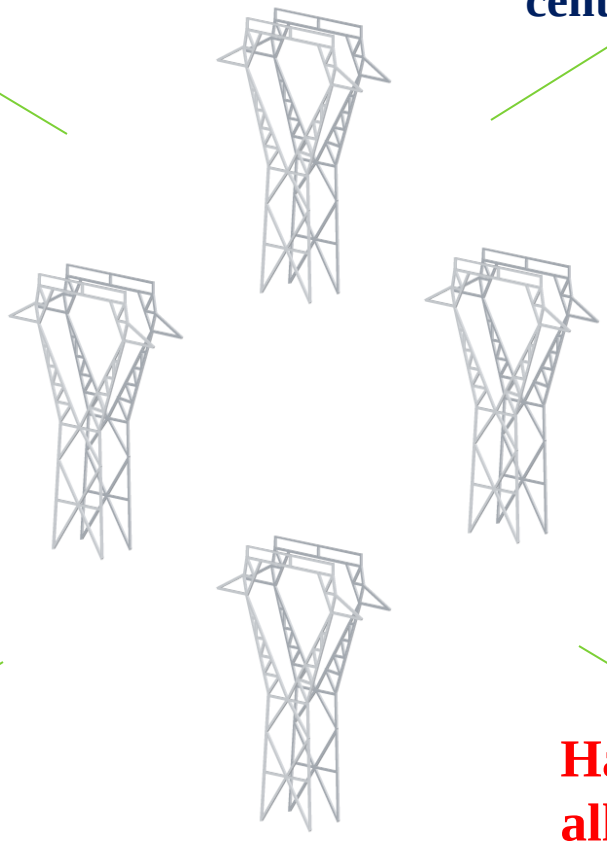
Tomorrow's Choices …



Future Grid – Smart(er) Grid

Wide area monitoring and control systems

Coordinated, full energy management and full integration of DG with large central power generation



Extensive small, distributed generation close to end user

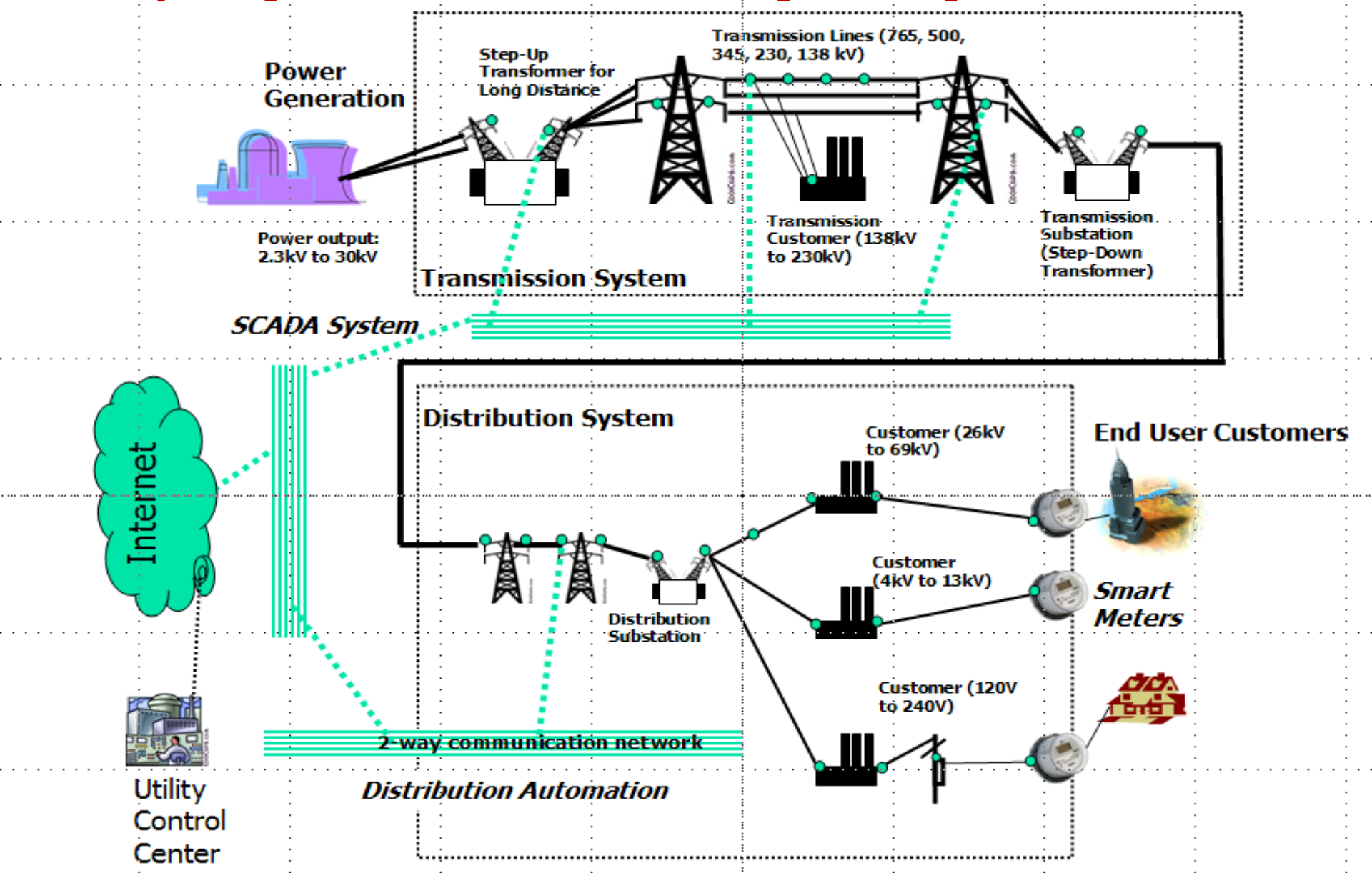
Secure, reliable and green power supply

Customer driven value added services

Harmonized legal framework allowing cross border power trading

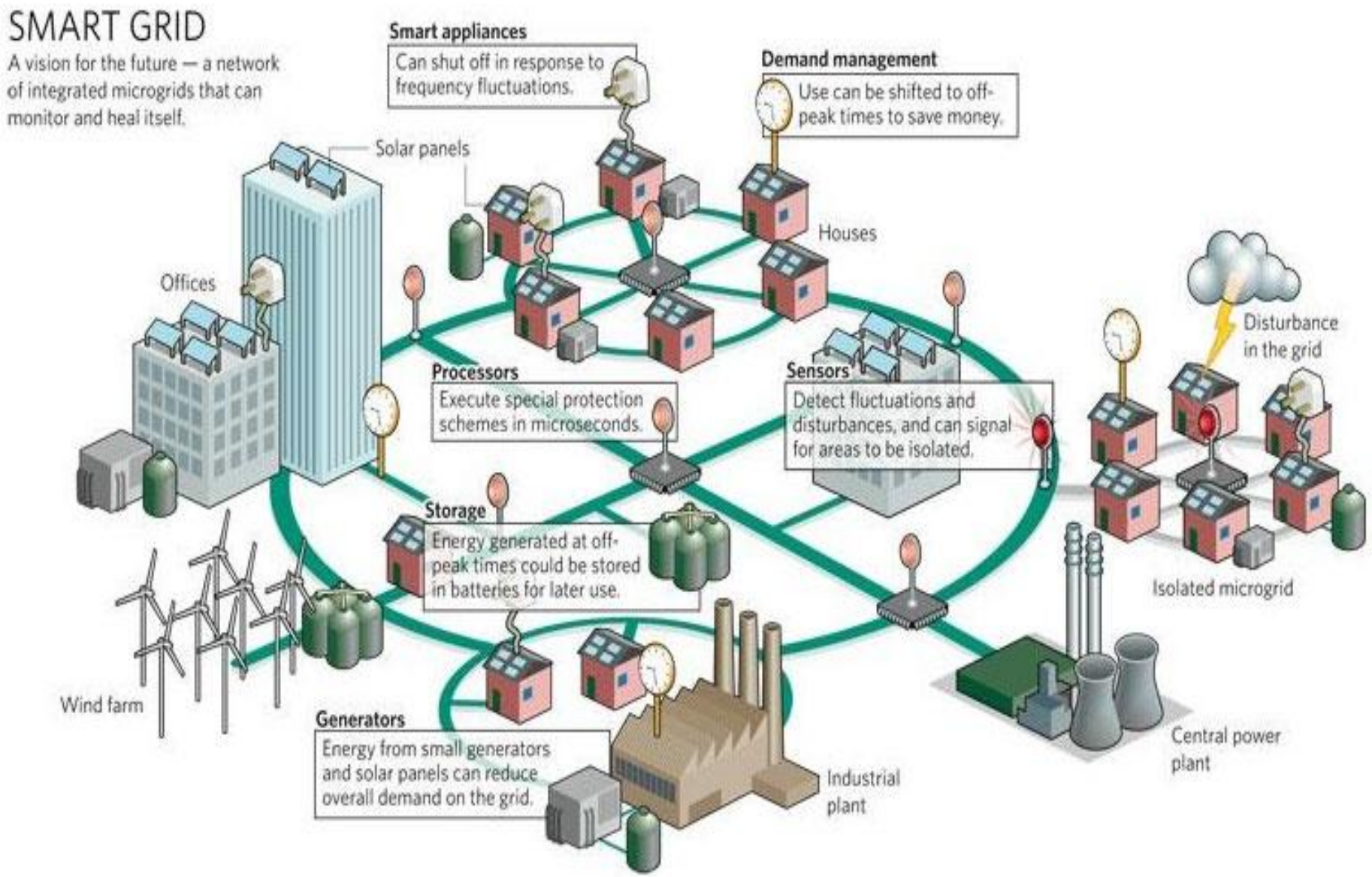
What a Smart Grid would look like?

Two-way integrated communication, adaptive, responsive, wider control



What a Smart Grid would look like?

Sensors throughout, self healing & monitoring, remote check & test



Source: http://vtsenvirogroup.wordpress.com/2009/05/19/you-think-youre-so-smart-grid/

Features of a Smart Grid

Ref: DOE document at http://www.oe.energy.gov/smartgrid

Self-Healing to correct problems early

Distributed assets and information

Integrated to merge all critical information

More Secure from threats from all hazards

Interactive with consumers and markets

Optimized to make best use of resources

Predictive to prevent emergencies

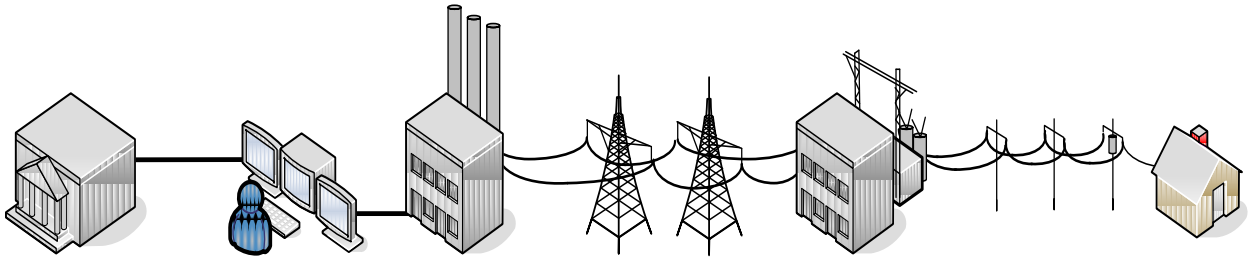
Existing Grid	Intelligent Grid
Centralized Generation	Distributed Generation
One-Way Communication	Two-Way Communication
Electromechanical	Digital
Hierarchical	Networked
Few Sensors	Sensors Throughout
Blind	Self-Monitoring
Manual Restoration	Self-Healing
Failures and Blackouts	Adaptive and Islanding
Manual Check/Test	Remote Check/Test
Limited Control	Pervasive/Wider Control

Ref: Hassan Farhangi, "The Path of the Smart Grid", *IEEE Power and Energy Magazine*, Jan. 2010, pp.18-28

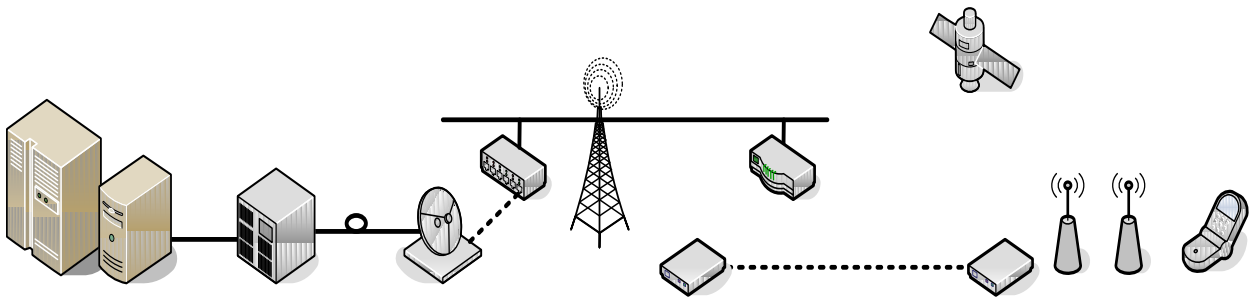
Merging Two Technologies

The integration of two infrastructures… securely…

Electrical Infrastructure



Information Infrastructure



***Source: EPRI® Intelligrid* at http://intelligrid.epri.com**

Smart Grid Advantages

Operational Efficiency

Reduced Onsite Premise Presence / Field Work Required

Shorter Outage Durations

Optimized Transformer Operation

Standards & Construction

Improved Network Operations

Reduce Integration & IT maintenance cost

Condition-based Asset Maintenance / Inspections

Energy Efficiency

Reduced Energy Losses

Active/Passive Demand-side Management

Smart Grid

Customer Satisfaction

Enable Customer Self-Service / Reduce Call Center Inquiries

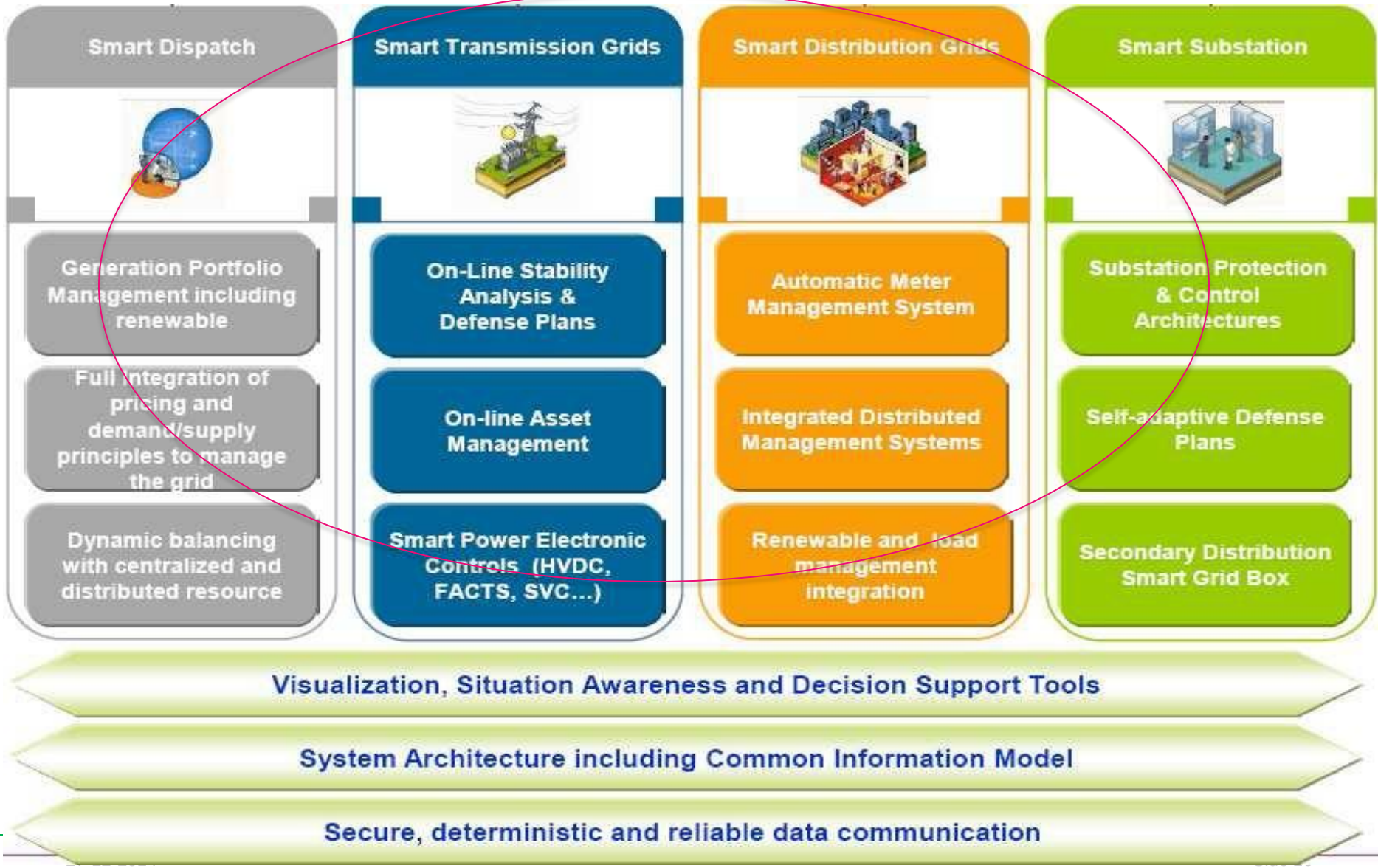
Improved Revenue Collection

Environmental Impact

Reduced Greenhouse Gas Emissions

Delayed Generation & Transmission Capital Investments

Smart Grid Environment



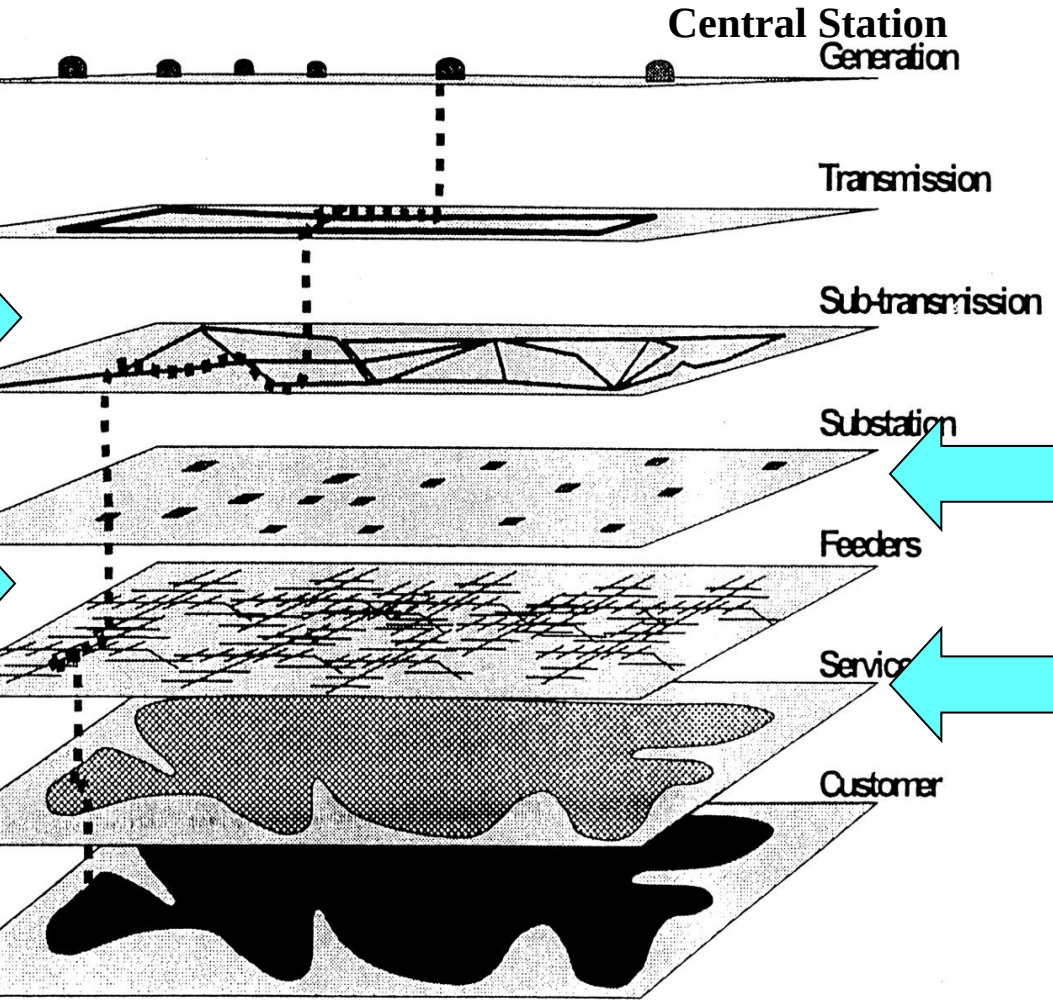
Source: Generation Dispatch, AREVA – IEEE Smart Grid Conference January 2010.

Interconnecting Distributed Power Systems

Wind Energy

Fuel Cells

Solar Energy



Combustion Engines

MicroTurbines

The overall power system is traditionally viewed in terms of 7 layers; each performing its function from central station generation supplying power out to customers.

Sahara / Concentrating Solar Power

Source: ABB

Solar Energy Policy in India

- **National Action Plan on Climate Change**
  - **–Prime Minister's Office; 30th June 2008**
- **Ministry of New and Renewable Energy (MNRE)**
  - **– http://mnes.nic.in/**
- **Support for research in solar energy harnessing**
  - **– Department of Science and Technology**
- **Promotion of use of solar energy**
- **Support at the central and state government levels**

National Action Plan on Climate Change

Announced by Prime Minister on 30th June, 2008

- National Solar Mission
- National Mission for Enhanced Efficiency
- National Mission on Sustainable Habitat
- National Water Mission
- National Mission for Sustaining the Himalayan Ecosystem
- National Mission for a "Green India"
- National Mission for Sustainable Agriculture
- National Mission on Strategic Knowledge for Climate Change

Electricity Generation Cost (Per kWh)

Energy Source	Cost
Combined cycle gas turbine	3 ¢ -5 ¢ (Rs.1.20-Rs.2.00)
Wind	4 ¢ -7 ¢ (Rs.1.60-Rs.2.80)
Biomass gasification	7 ¢ -9 ¢ (Rs.2.80-Rs.3.60)
Remote diesel generation	20 ¢ -40 ¢ (Rs.8.00-Rs.16.00)
Solar PV central station	20 ¢ -30 ¢ (Rs.8.00-Rs.12.00)
Solar PV Distributed	20 ¢ -50 ¢ (Rs.8.00-Rs.20.00)

http://www.solarbuzz.com/StatsCosts.htm (accessed 14.11.2010)

Smart Grid Initiatives

- **US Dept. of Energy**
  - **GridWise & GridWorks**
- **Modern Grid Initiative (NETL: National Energy Technology Lab)**
- **GridWise Alliance (US industry group)**
- **IntelliGrid (EPRI)**
- **CERTS – Consortium for Electric Reliability Technology Solutions (USA)**
- **SmartGrids (European Union)**
- **Integration of Decentralized Energy Resources Program (NRCan Canada)**
- **NIST Special Publication 1108, NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0 , January 2010**
- **The Smart Grid Vision for India's Power Sector: A White Paper, under USAID DRUM project, prepared by PA Government Services, Inc., India**

Smart Grid Activities in India

- **India Smart Grid Forum**
- **India Smart Grid Forum (ISGF)- launched by Union Power Minister on May 26, 2010**
  - **A non-profit voluntary consortium of public and private stakeholders with the prime objective of accelerating development of Smart Grid technologies in the Indian Power Sector**
- **India Smart Grid Task Force (ISGTF)**
  - **An inter ministerial group and will serve as Government's focal point for activities related to "Smart Grid".**
- **Many Utilities have started their individual activities at different levels**
- **India Smart Grid forum (ISGF)(website http://173.201.177.176/isgf) and India Smart Grid Task Force (ISGTF) (website http://www.isgtf.in) constituted for the systemic growth of Smart Grid in the country**
- **Several *pilot city projects* are being funded by MOP. Smart City (100) being coordinated by Ministry of Urban Development.**

Smart City Pilots funded by MOP- Area Proposed	Functionality Proposed
Electrical Division, No. I, Agartala	AMI R, AMI I, PLM
Panipat City, SubDivision	AMI R, AMI I, PLM, OMS, Renewable Integration
SAS Nagar , Mohali	AMI R,AMI I,PLM
Siltara, Chattisgarh	AMI I, PLM
Sanganer subdivision of Jaipur	AMI R, AMI I, PLM
ESD Kala Amb Under Electrical Division, Nahan	AMI I, OM, PLM, PQM
Siliguri town, Darjeeling District	AMI R, AMI I, PLM
Div 1 of Puducherry	AMI R, AMI I
Mysore additional City Area Division	AMI R, AMI I, OM, PLM, MicroGrid/ DG
Spread over the Kerala	AMI I
Guwahati Project Area	PLM, AMI R, AMI I, OM, DG, PQM
Baramati, Pune	AMI R, AMI I, OM
Naroda / Deesa	AMI R, AMI I, OM, PLM, PQM
Jeedimetla Industrial Area	AMI R, AMI I, PLM, OM, PQM

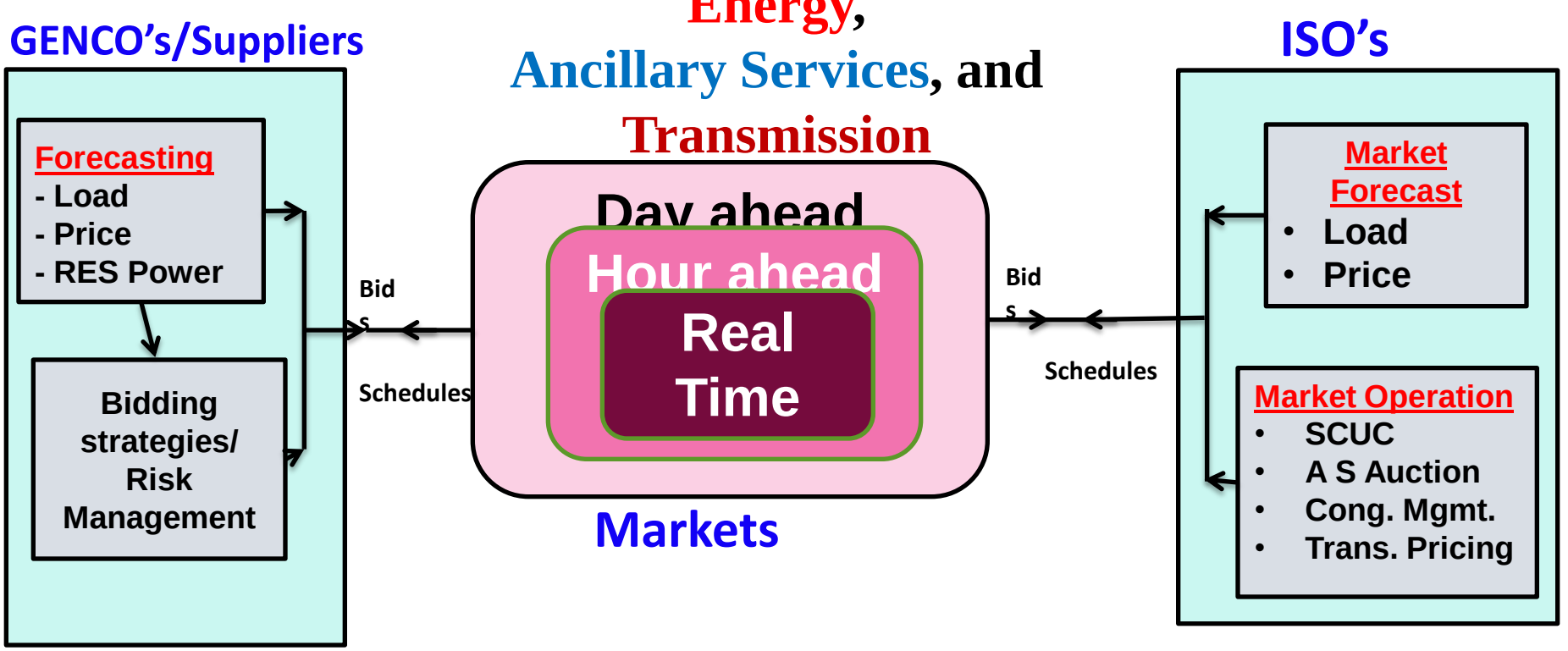
Courtesy: Powergrid

Challenges in Smart Grid Implementation

- **Increase in system Operational Complexity**
- **More business oriented attitude**
- **Large Data Handling**
- **Information Security**
- **Cost-effecting implementation (including ICT)**
- **Utilization of Demand Response**
- **Redesigning of electricity market structure**
- **Fast analysis tools**
- **Integration of renewable energy sources**
- **Power Quality and Many more…**
- **Requirement of Accurate Forecasting approaches**

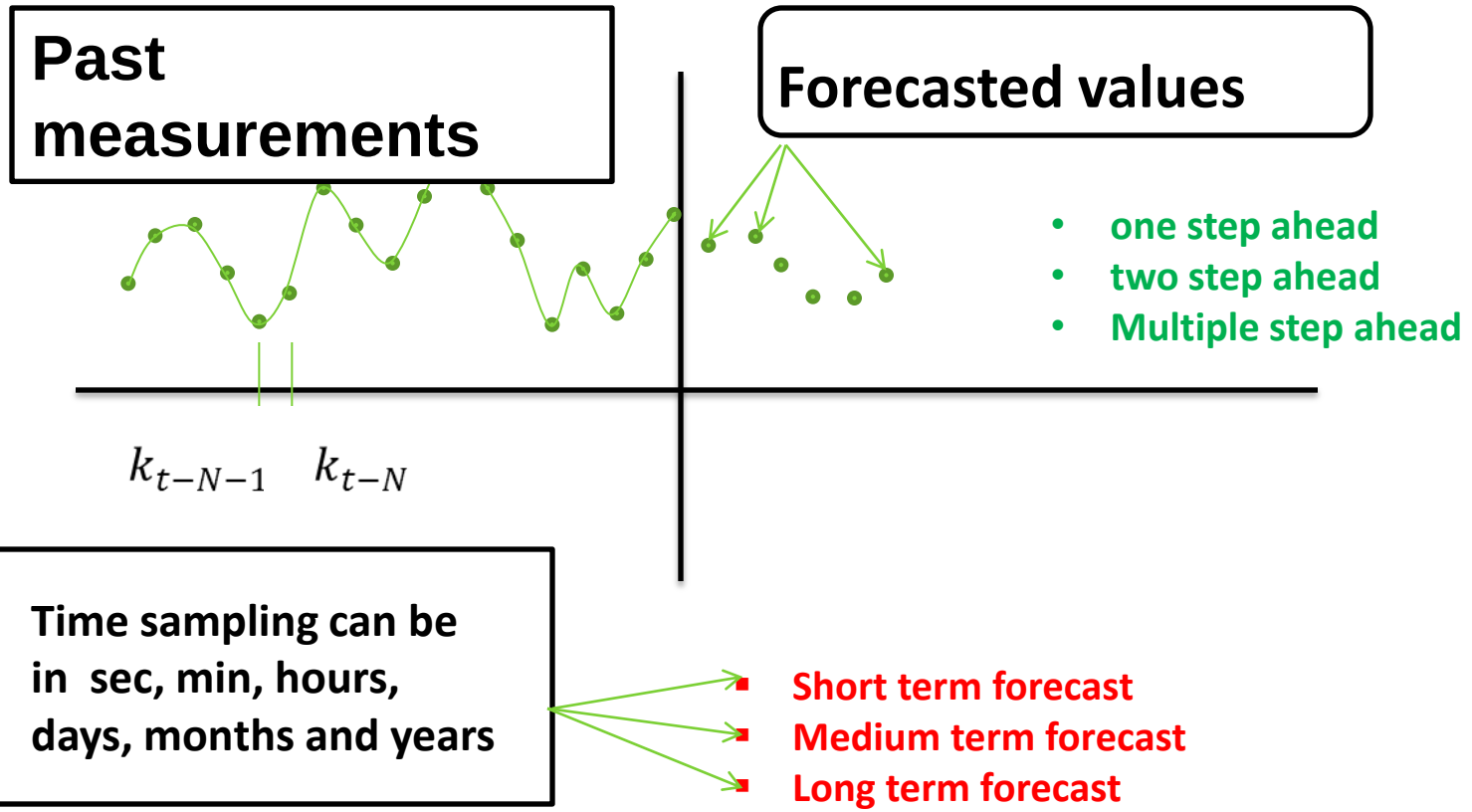
Role of Forecasting in Electric Power System

Electricity Market Operation



Basic Definition of Forecasting

Forecasting is a problem of determining the future values of a time series from current and past values.



Forecasting Approaches

Linear Regression Models : **(AR, ARMA, ARIMA, GARCH, etc.)**

The forecast value is linearly dependent on the past historical values of the time series

- **Time Series Modeling – Maximum Likelyhood Estimation, Least Square Estimation Methods are used for Parameter Estimation.**
- **State Space Modeling- Kalman Filtering Techniques used**

Limitations of Linear Regression Models

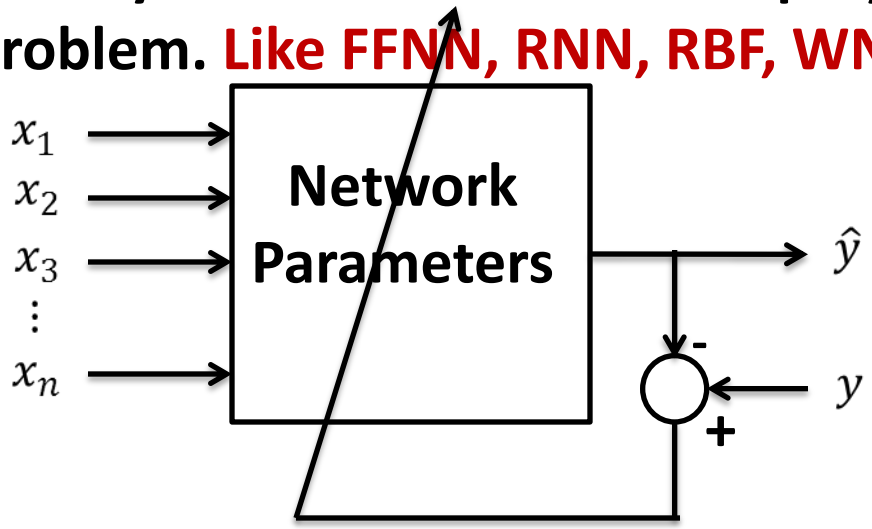
1. **As they are linear models, they cannot capture the non-linear relation between the independent and dependent variable.**
2. **The forecasting error increases rapidly with the increase in look-ahead time.**
3. **The model parameters have to be updated very frequently.**

Forecasting Approaches .....contd

Non-Linear Regression models:

$$X_t = F(X_{t-1}, X_{t-2}, X_{t-3}, \cdots, u_t, u_{t-1}, u_{t-2}, \cdots) + \varepsilon_t$$

Artificial Neural Networks (ANN) are well established in function approximation, many variants of NNs are employed in the field of forecasting problem. Like FFNN, RNN, RBF, WNN.



Back-Propagation Algorithm, Evolutionary based Optimization methods like GA, PSO are also applied for network training.

Input variables are selected using ACF and PACF.

Other Methods..

- **Fuzzy Logic**
- **Adaptive Neuro-Fuzzy Inference System (ANFIS)**
- **Data Mining techniques like clustering and Support Vector Machines (SVM) based classification and Regression models.**
- **Wavelet pre-filtering based ANN and Fuzzy models.**

Conclusions

- For successful implementation of Smart Grid, a good forecasting tool, adoptive market mechanism and feasible interconnection grid code are necessary.
- It will require large deployment of DERs, micro-grids, WAMS in a distributed and networked manner.
- Modular integration approach, open protocol and common information (CIM) system need to be developed and deployed.
- Operation and Control of Smart Grid will be far more complex.
- There will be enormous Research Development and Demonstration efforts required by stakeholders: academia, industries, government and utilities together.


THANK YOU