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Modeling, Simulation and Optimization for the 21st Century Electric Power Grid

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EPRI

ELECTRIC POWER RESEARCH INSTITUTE

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EPRI's Mission…

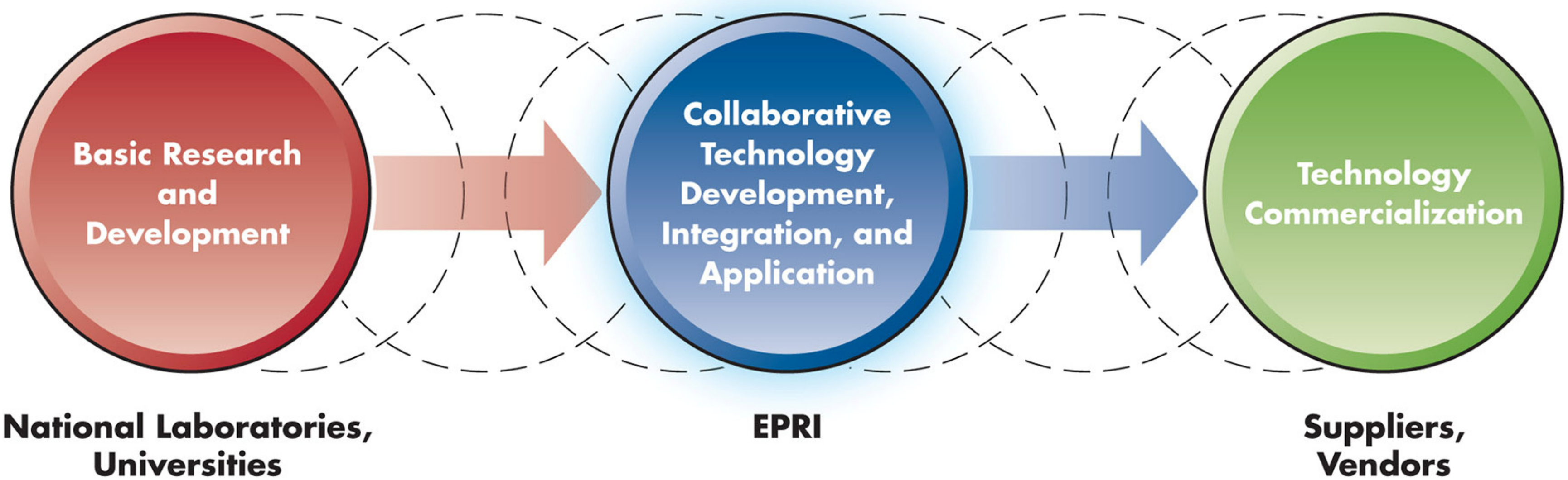
To conduct research on key issues facing the electricity sector…on behalf of its members, energy stakeholders, and society.

Our Members…

- 450+ participants in more than 40 countries
- EPRI members generate more than 90% of the electricity in the United States
- International funding of more than 18% of EPRI's research, development and demonstrations
- Programs funded by more than 1,000 energy organizations

Our Role…

Help Move Technologies to the Commercialization Stage…

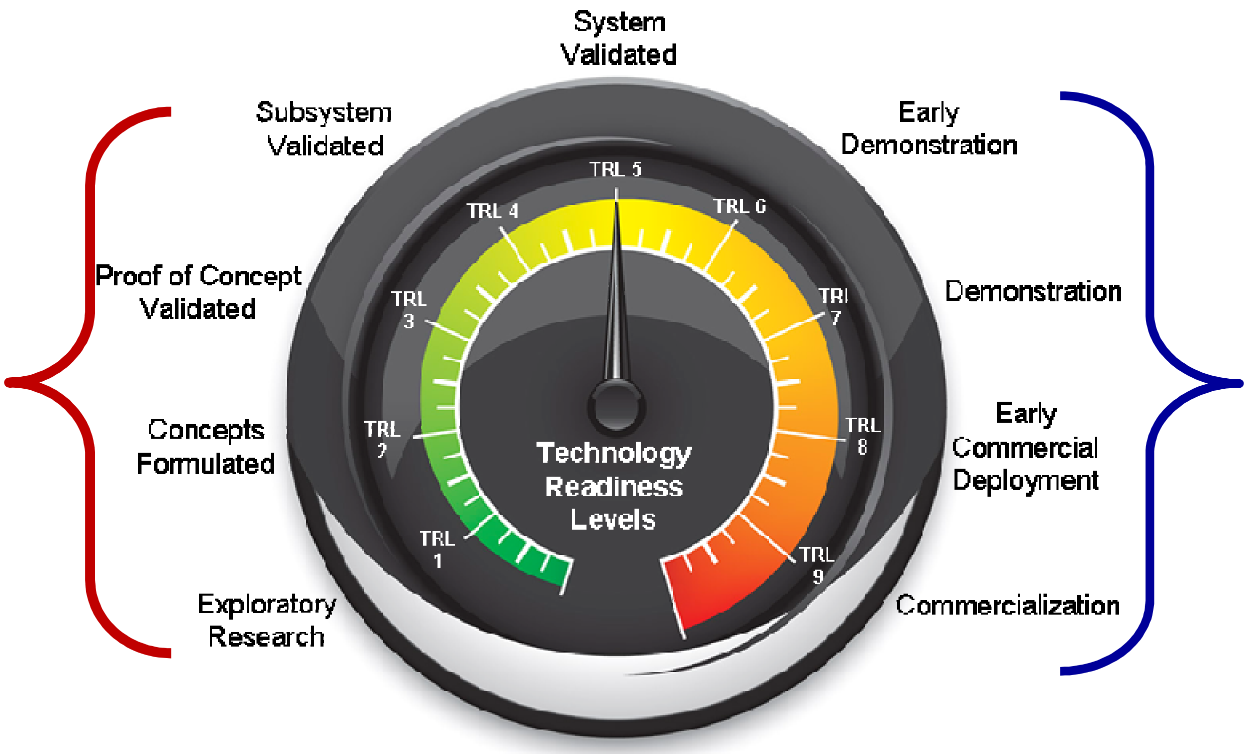


Technology Accelerator!

Technology Innovation Early Stage Research

Technology Innovation

~12% Fund

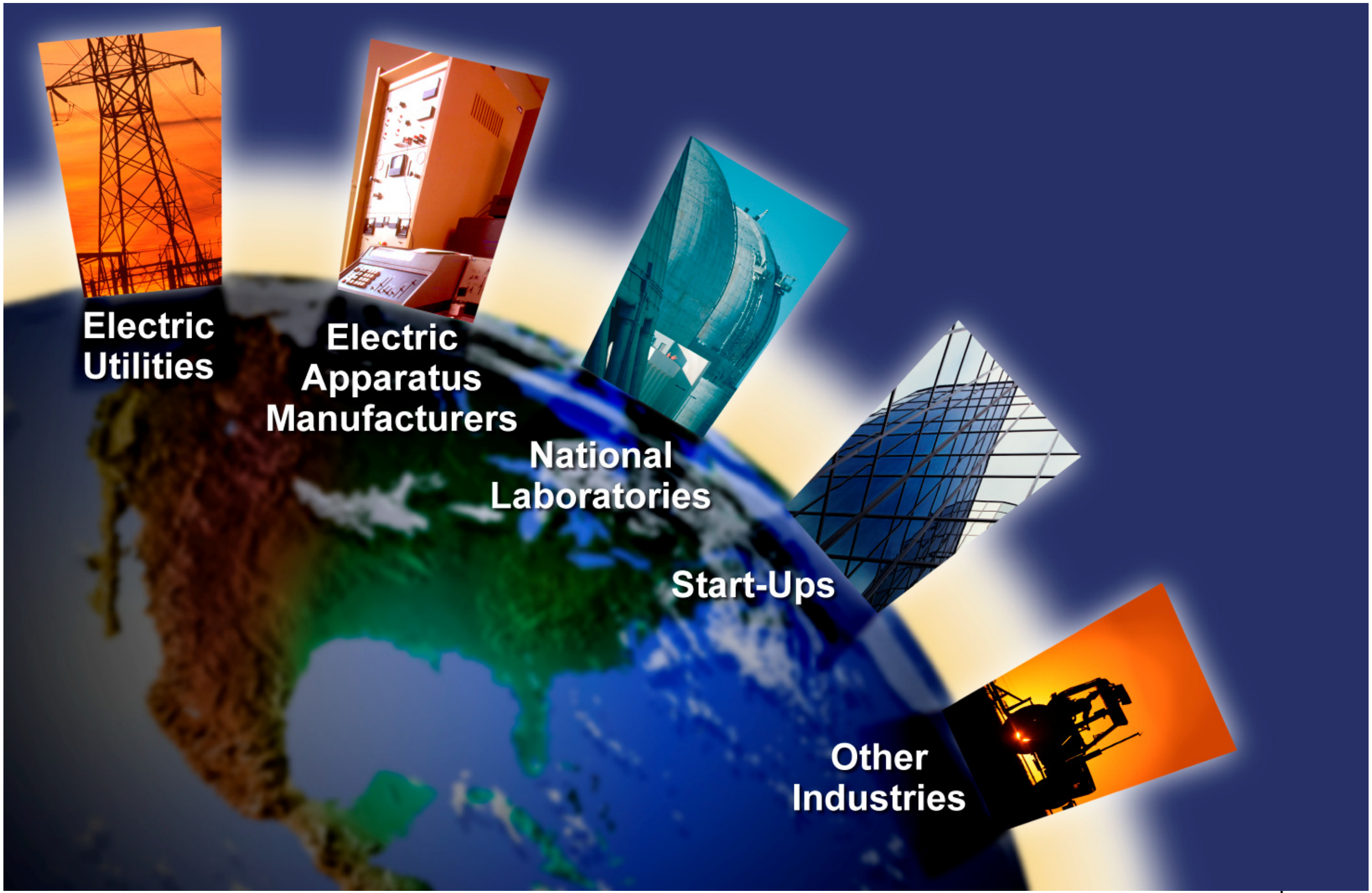


Sector Annual R&D Portfolio

~88% Fund

Technology Innovation is a "Pipeline of Ideas and Projects" to EPRI's Sectors to Move Technology From Concept to Diffusion

Working Together… to Shape the Future through *Innovation*



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Setting the Stage

Why are we all here?

Tectonic Changes in the Electricity Grid

Original Basis for Project

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This white paper was prepared by Arshad Mansoor and Clark Gellings of EPRI

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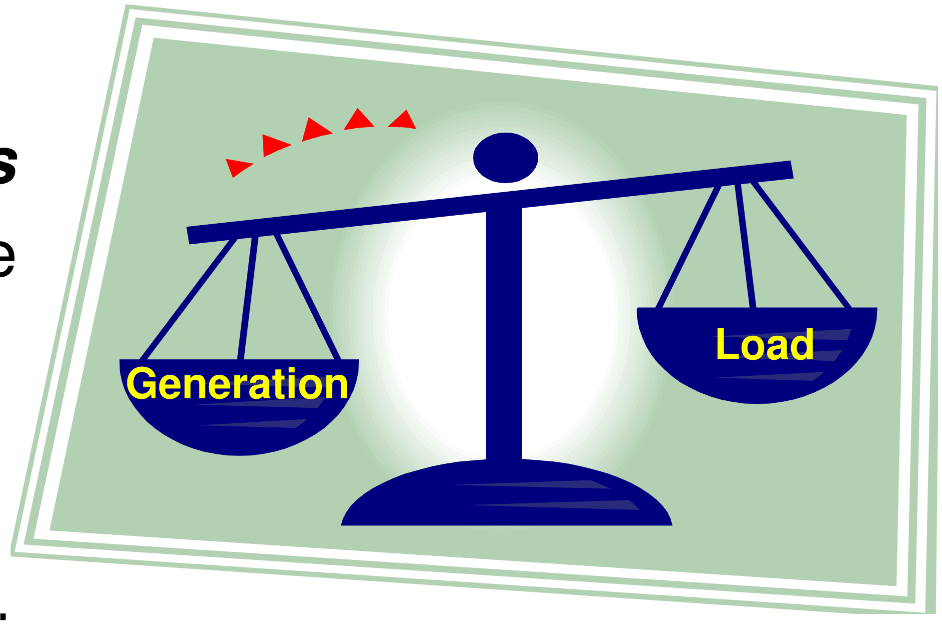
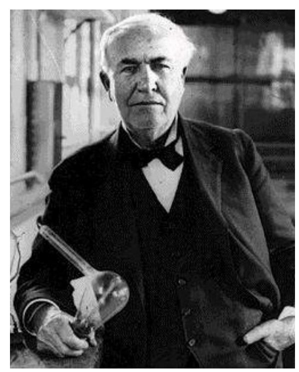
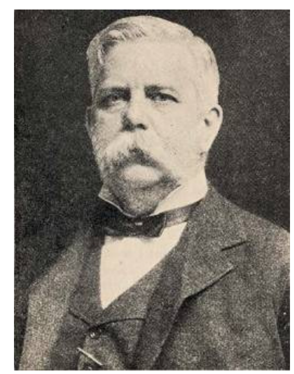
Grid Operating System 1.0

- ***Pearl Street until ~1950s***
- Edison and Westinghouse faced challenges in operating early power systems; specifically to enable reliable operation through control such that in any instant the total generation in a power system was "balanced against" total load.

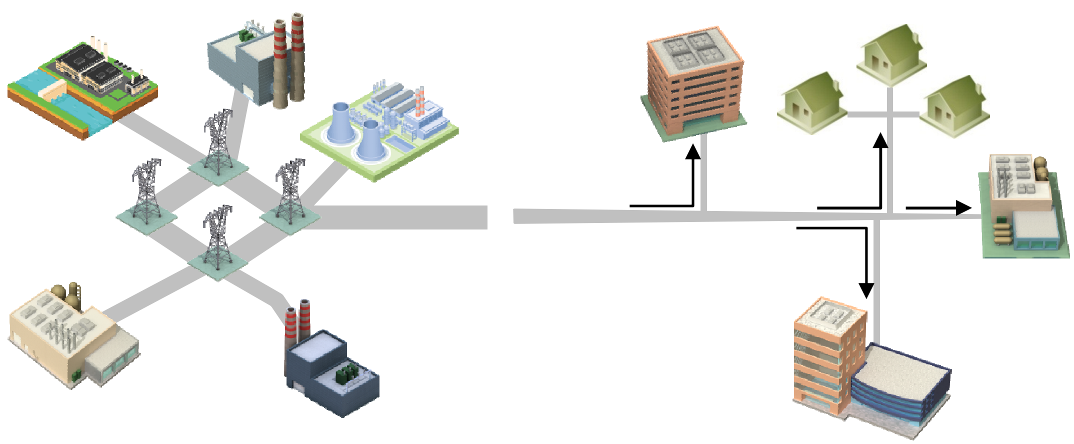






Grid Operating System 2.0

– ***1950s until today***
– ***Early SCADA systems & Current EMS systems & applications***
– Today's power system is largely comprised of large central station power generation connected by a high-voltage network or grid to local distributions systems which serve homes, businesses and industry. Electricity flows predominantly in one direction using mechanical controls.



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Grid Operating System 3.0

- ***Tectonic Changes in the Electricity Grid***
  - The power system is revolutionizing at an exponential pace into a highly interconnected, complex, and interactive network of power systems, telecommunications, the Internet, and electronic commerce applications
- ***Drivers of Change***
  - Variable Generation
  - Demand Response
  - Electric Vehicles
  - Smart Meters
  - Distributed Generation
  - PMUs
  - Communications

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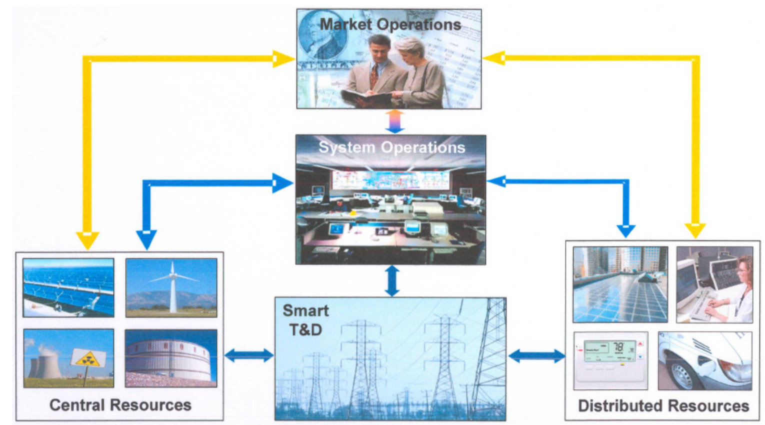
Why Grid Operating System 3.0?

- Existing grid operating system was not designed to meet the increasing demands of a digital society or the increased use of renewable power production.
- In the USA there is a national imperative to modernize and enhance the power delivery system and that modernization must include a new grid operating system.
- Tomorrow's grid operating system must facilitate high levels of security, quality, reliability, and availability of electric power; improve economic productivity and quality of life; and minimize environmental impact while maximizing safety.

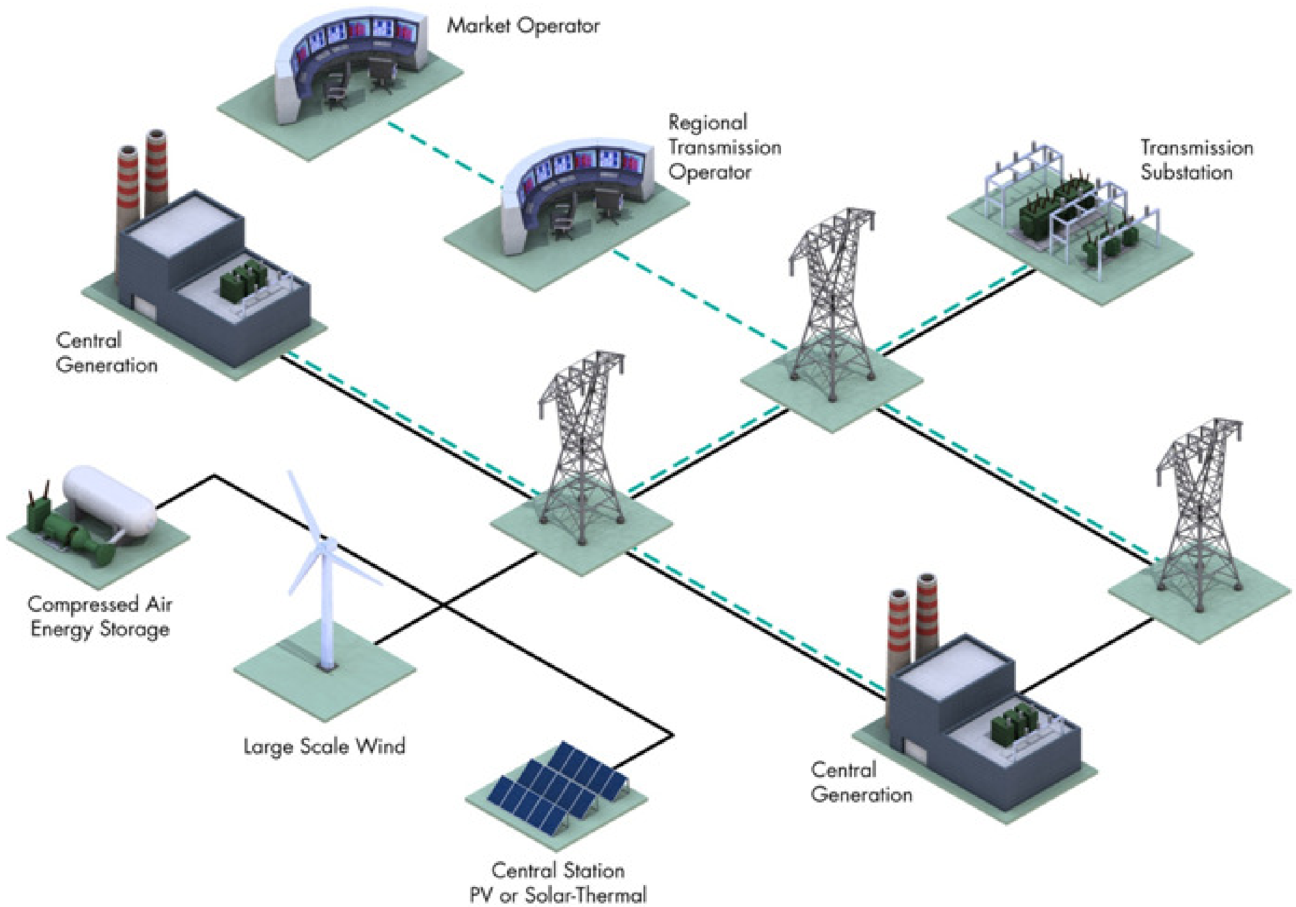
Grid Operating System 3.0 Functionality



- Geospatial Power System Model
- Advanced Protection and Control Functions
- State Measurement with Look-Ahead Capability
- Cyber Security
- Enable Active Participation by Consumers
- Accommodate All Generation and Storage Options
- Enable New Products, Services, and Markets
- Optimize Asset Utilization and Operate Efficiently
- Anticipate and Respond to System Disturbances (Self-Heal)
- Operate Resiliently Against Attack and Natural Disaster
- Effectively Integrate Local Energy Networks

Local Energy Networks

- Tomorrow's Bulk Power System



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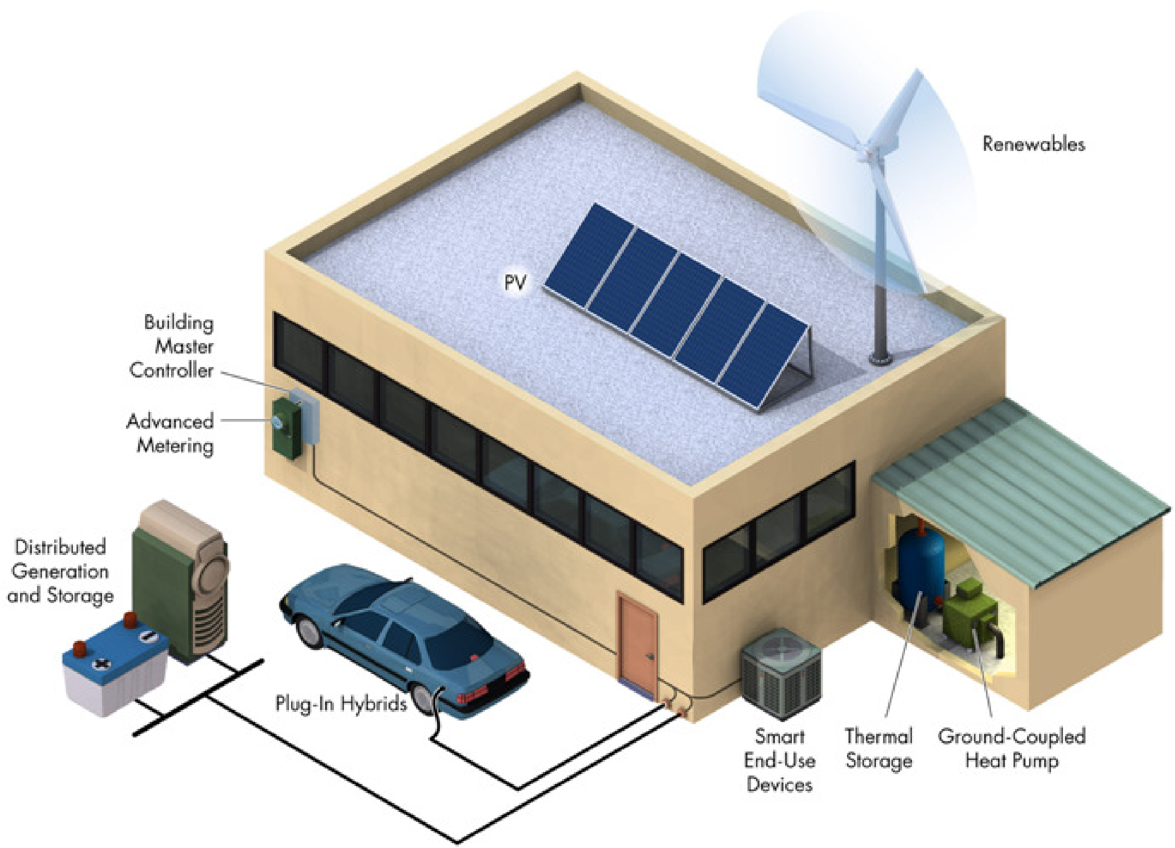
Local Energy Networks

- Building-Level Local Energy Network



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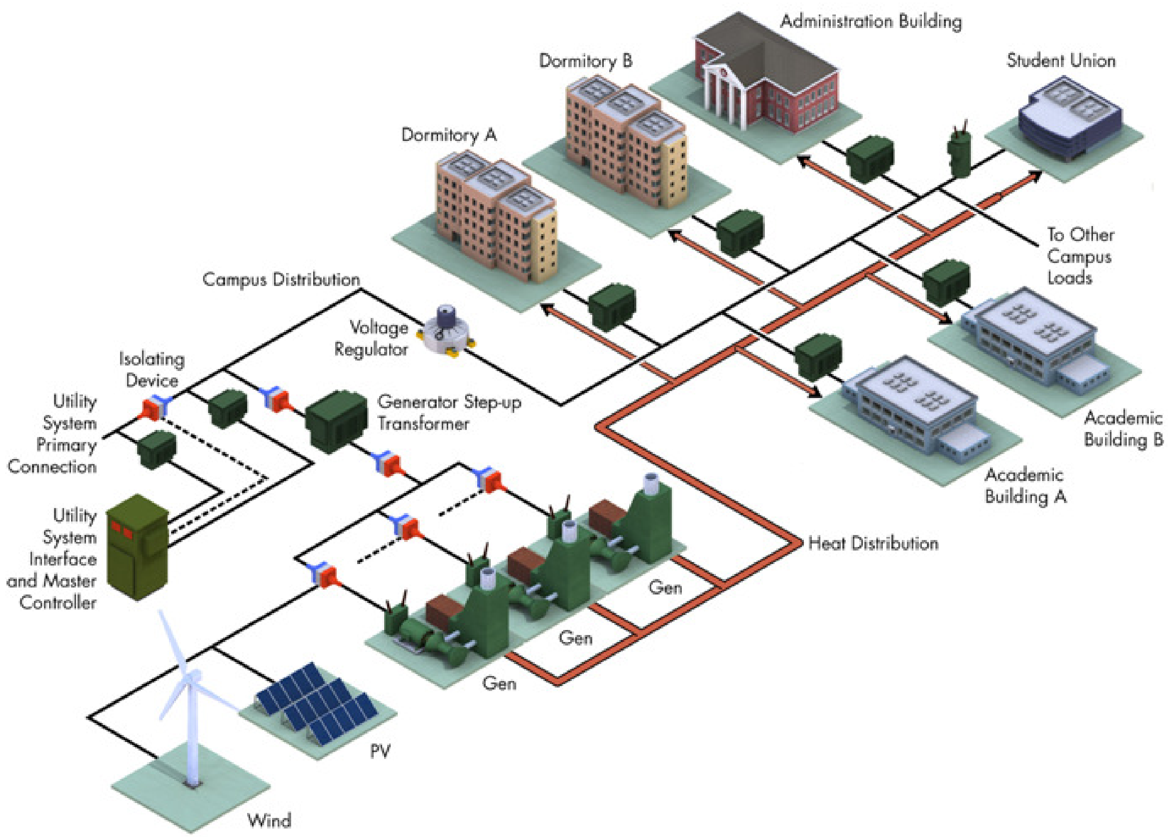
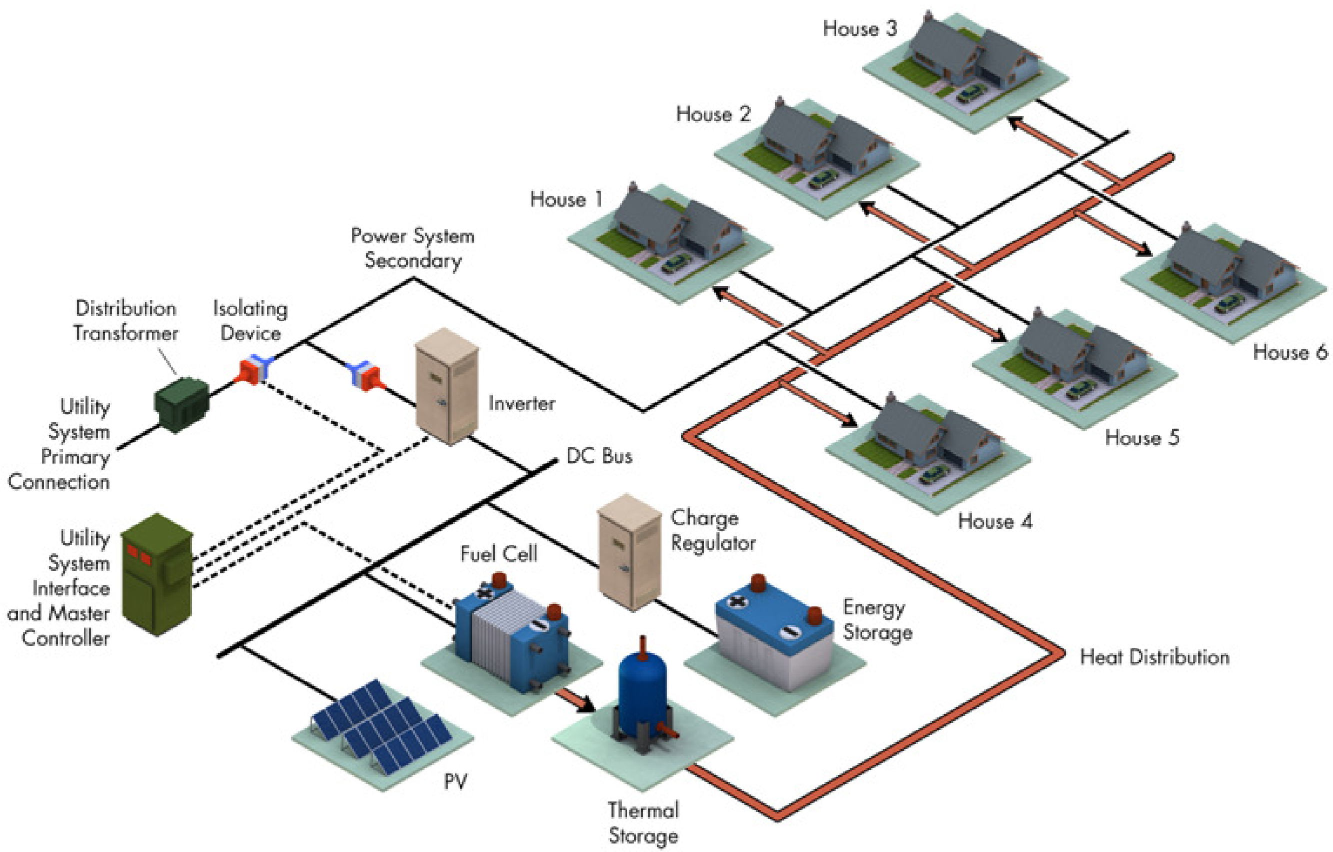
Local Energy Networks

- Campus-Level Local Energy Network

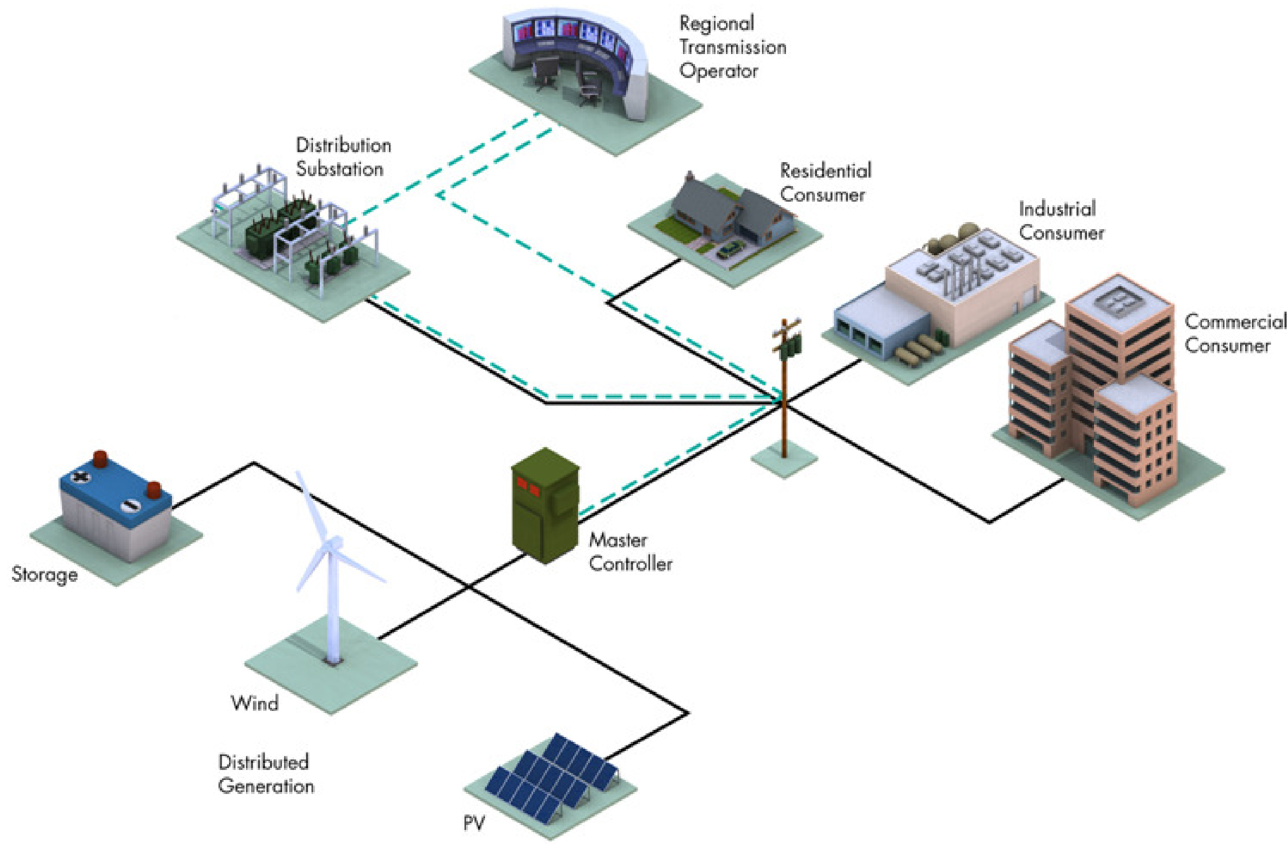


Local Energy Networks

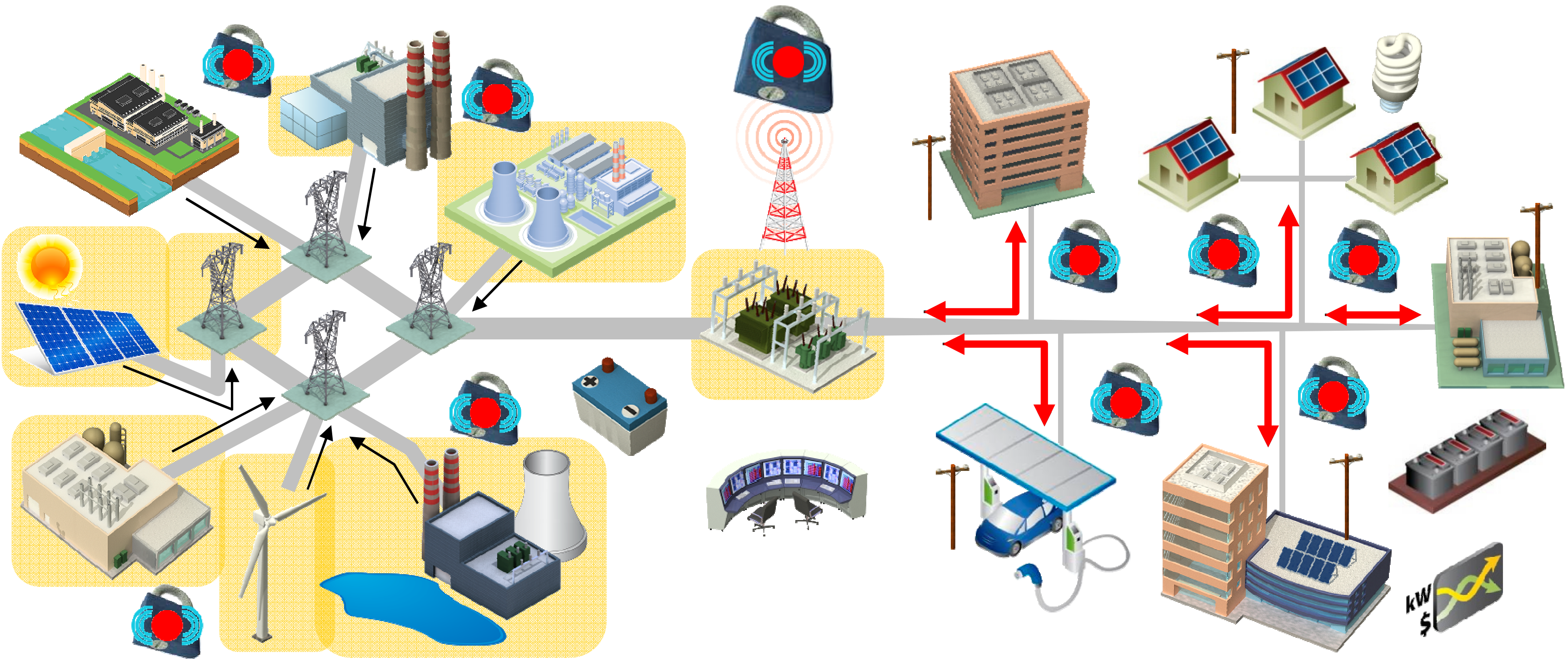
- Community-Level Local Energy Network



Tomorrow's Distribution System



Tomorrow's Power System



Managing Future Power System Complexity will Require a New Grid Operating System

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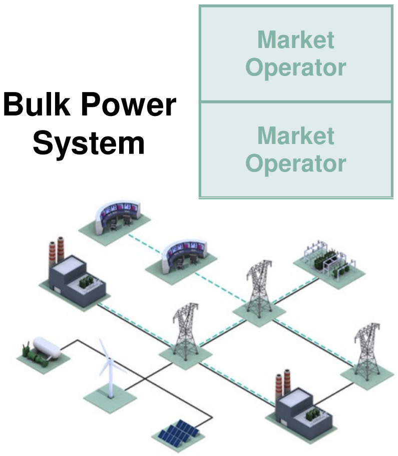
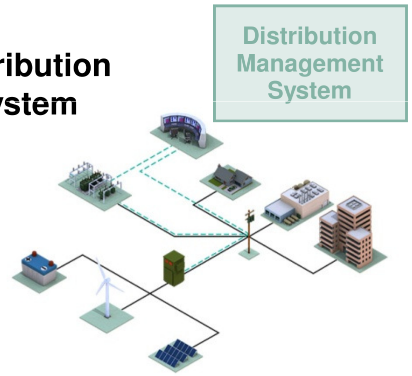
Example Grid 3.0 Architecture

- What information is needed from each node?
- What data is needed?
- What sensors are needed?
- How is data collected and managed?
- Where does computation occur?
- What controls are needed?

Bulk Power System

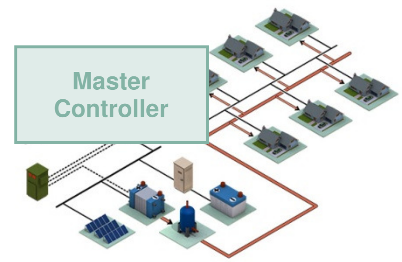


Distribution System

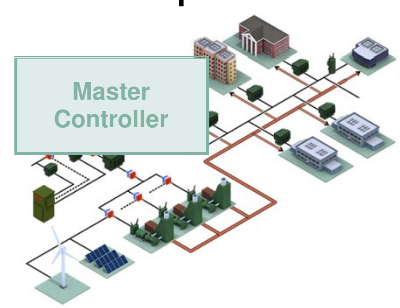


- What is the decision hierarchy?
- Optimization algorithms for reliability, security, stability, economics, environment, etc.
- Where will forecasting of resource availability, renewable production and demand occur?

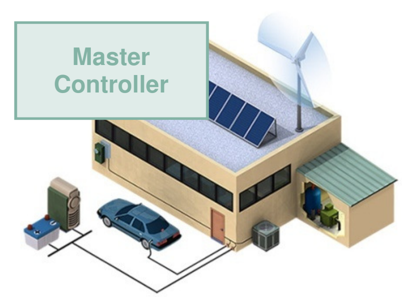
Community LEN



Campus LEN



Building LEN



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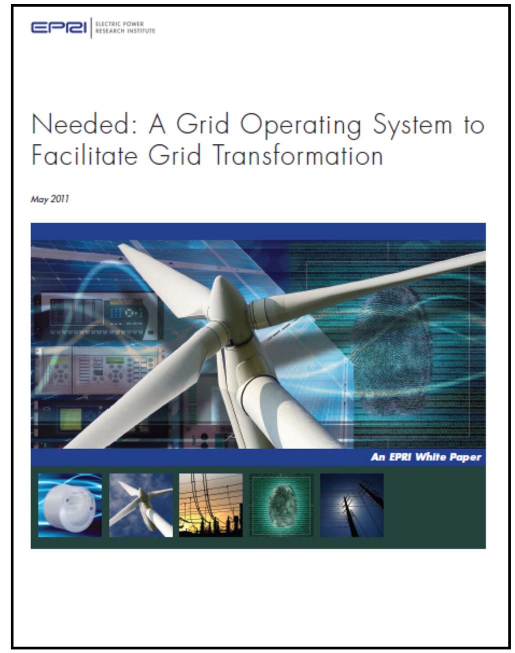
Collaboration to Develop Grid 3.0

- **EPRI can be a catalyst** in the development of Grid 3.0 by becoming a facilitator among the stakeholders
- Organize a **multi-day workshop** of the industry's best minds to put together a **comprehensive plan**.
- That **plan** will develop a 24-month vision of an **architecture and a requirement driven specification**.
- **Conducted in an open environment** such that the implementation and ultimate innovative development of products and systems can be conducted by vendors.
- **Critical** that the **industry respond** to this call for action **to embrace** this innovation challenge to **develop Grid Operating System 3.0.**
- **EPRI will provide seed funding** for the first phase of this effort from its Technology Innovation Program.
- **Additional** R&D funding **resources** and dedicated **researchers** from key institutions will ultimately be needed to make Grid 3.0 a reality.



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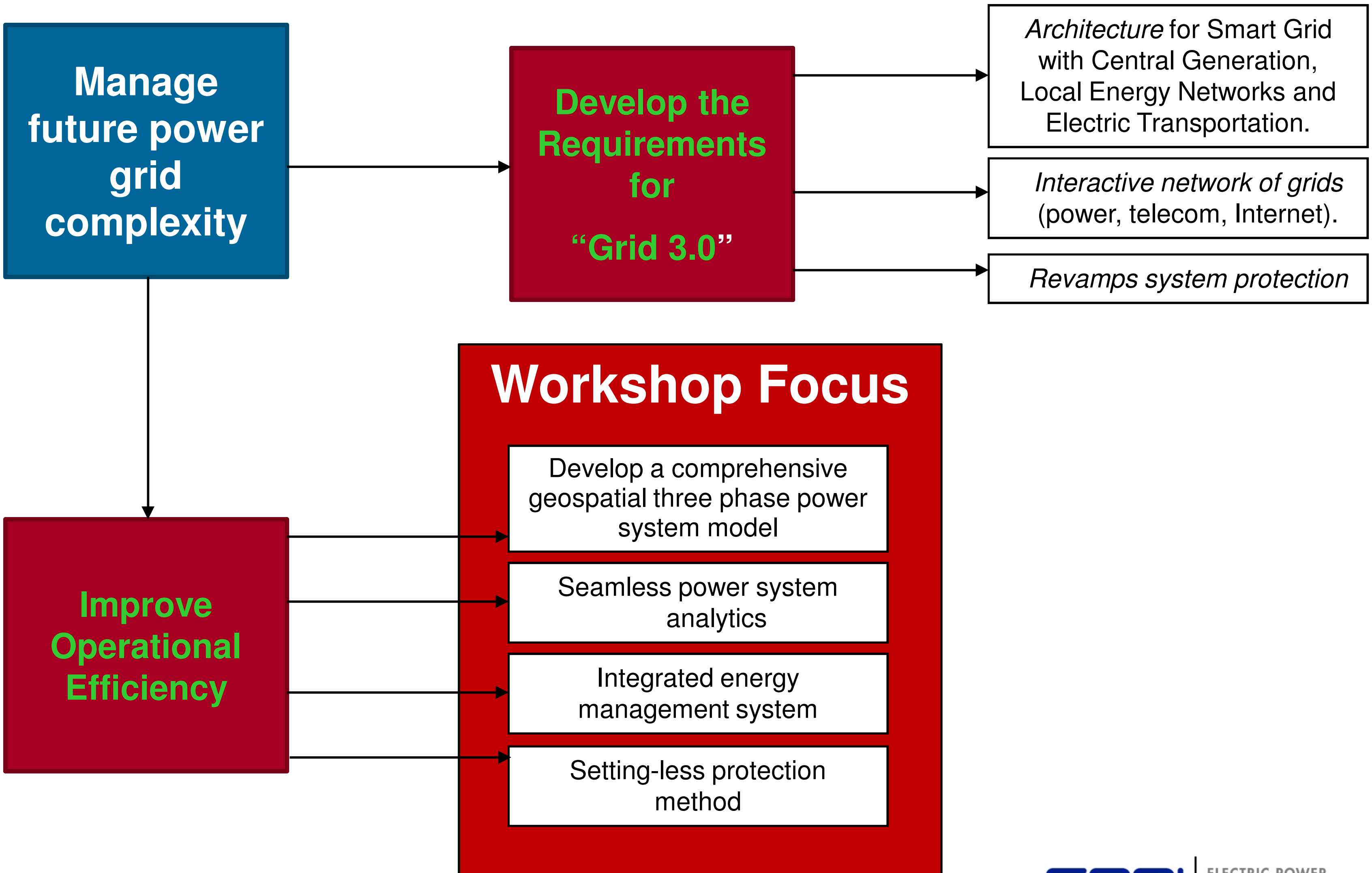
Grid Transformation and EPRI Activities



Seamless geospatial power system model

- The explosion of data from “Smart Grid” Intelligent Electronic Devices (IEDs) and the deployment of distributed generation in the form of wind and solar systems has significantly increased expectations of utility systems and stressed the analytics, control schemes, back office systems and applications including devices that are currently deployed to manage and control the grid.
- Increasingly systems are being asked to provide an integrated geospatial view of diverse applications as power flow, fault detection and location, critical asset identification, outage management, work force utilization, distributed generation status and more
- One of the problem areas of all these systems is namely the lack of a standard, seamless data model that can be used across all the applications.

Seamless Power System Analytics

- The current approach to power system analysis has developed over the last several decades in a piecemeal fashion where the various applications run separately using their own system models and formats.
- Although these tools have improved, the programs are still built upon core technology and software architectures from decades ago, each developed individually, for its own unique purpose, often with legacy code implementing old algorithms, all designed for sequential computing hardware.
- External data interfaces are unwieldy, the user interface is weak, and there is usually no centralized engine to house the numerical methods used in the application.
- Updating or extending such software is very tedious; it is often easier to create new software completely. Achieving interoperability for such applications is extremely cumbersome if not impossible.

Integrated Energy Management System

- Control centers that control the transmission-generation grid, known as energy management systems (EMS) are organized in a hierarchy of two or three levels depending on the size of the interconnected grid.
- These EMS, first using digital computers in the 60s, have evolved gradually over the last decades but now major transformation is essential to support emerging power system operations and grid objectives.
- The expanding power grid requires operation and control of system behavior that occurs at temporal and spatial scales, different from the scales traditionally considered by the EMS.
- New technologies in measurements, communications, computation and control make such transition to a new generation of EMS possible.
- These same technologies are increasingly being applied to the distribution system and new generations of distribution management systems (DMS) are now being deployed that are increasingly connected to the EMS.

Setting-less Protection Method

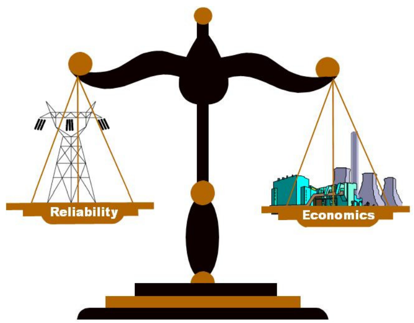
- The capabilities of protective relays have increased dramatically
- Training requirement for protection engineers is ever increasing and requiring even broader based knowledge that before.
- Current protection approaches require analysis of expected operating modes while the future tends toward
- The approaches to be examined are adaptive relaying, component state estimation approach, substation based protection and pattern recognition based approach.

The Big Challenge!

- Electricity as a Commodity Cannot be Stored!

At least not yet

- Electricity Demand changes from instant to instant
- Supply needs to change instantaneously to meet Demand…



- If supply does not equal demand, Frequency goes off-normal (not 60Hz)… which results in:
  - Protective relay trips of generating units, loads, etc.
  - Potential for a cascading blackout..
  - And your electric alarm clocks would not keep correct time! ☺

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Energy Management System - EMS

- Energy Management Systems (EMS) capabilities have evolved over the past five decades (since the 1965 blackout)
- EMS manage the "physical flow" of electricity in the grid.
  - Operate the electric grid within safe limits
  - Operate the system reliably – "Prevent Blackouts"
  - Automatically adjust generation to follow Instantaneous customer load changes (Remember, Electricity Cannot be Stored….)
  - Identify potential risks and take preventive action
  - Expedite restoration of customers after an emergency

Challenge / Path Forward

- Increasing complexity of operating the power delivery grid due to renewables, electric vehicles, etc and limited availability of experienced human resources are driving the need to simplify the overall process.

Integrated Energy Management System.

- Development of an EMS (Grid OS 3.0) that accommodates these developments and be positioned to adapt to future needs is necessary to avoid blackouts, provide for the smart grid and accommodate future energy needs also requires:
  - Fully Integrated Geospatial Power System Model
  - Seamless Power System Analytics
  - Improvements in protection methods

Results to date

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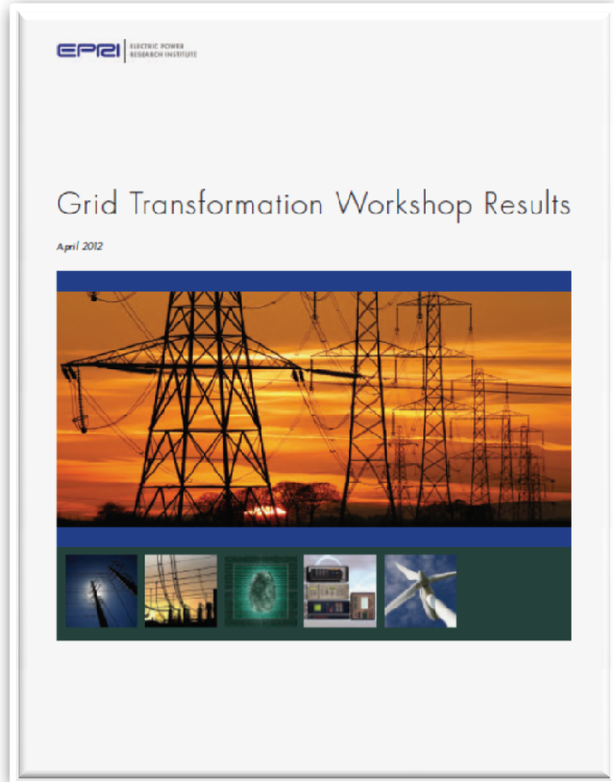

Product ID 1025087-Grid Transformation Workshop Results

Together…Shaping the Future of Electricity