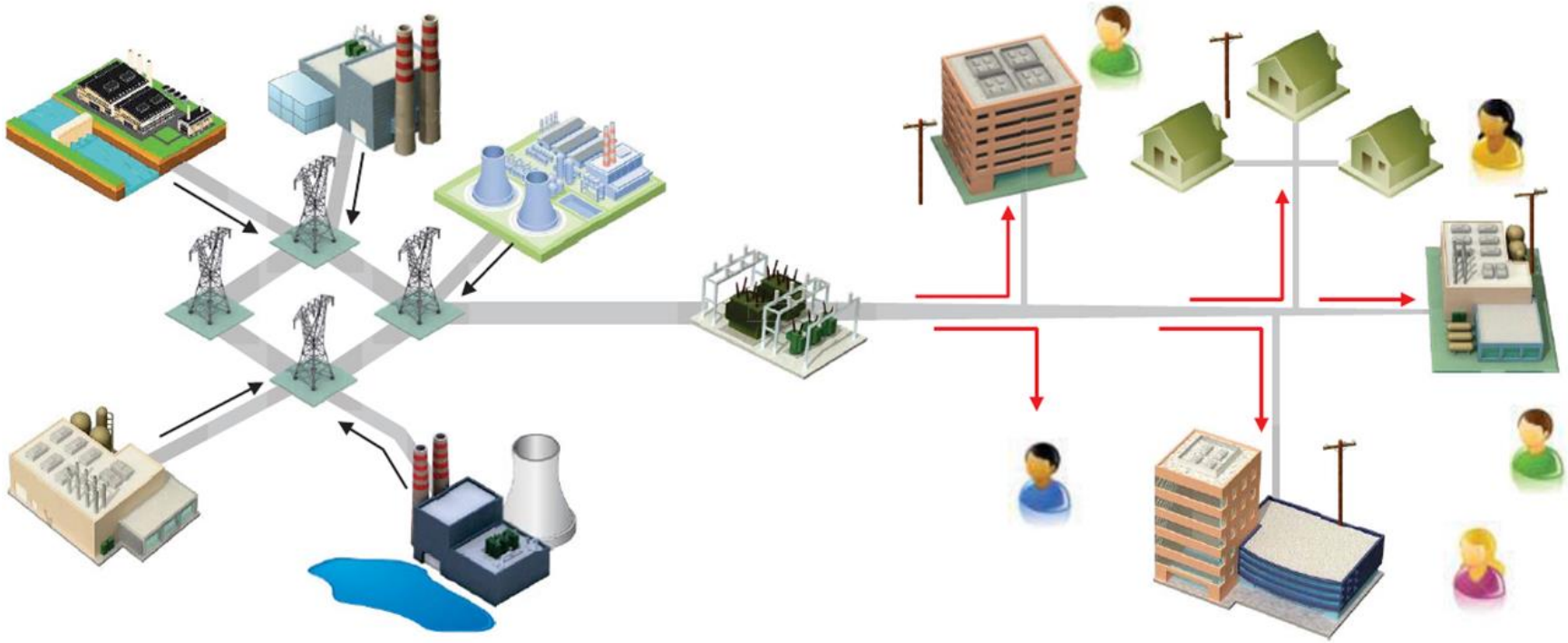
CLEMSON UNIVERSITY

Driving economic growth, innovation, and workforce development

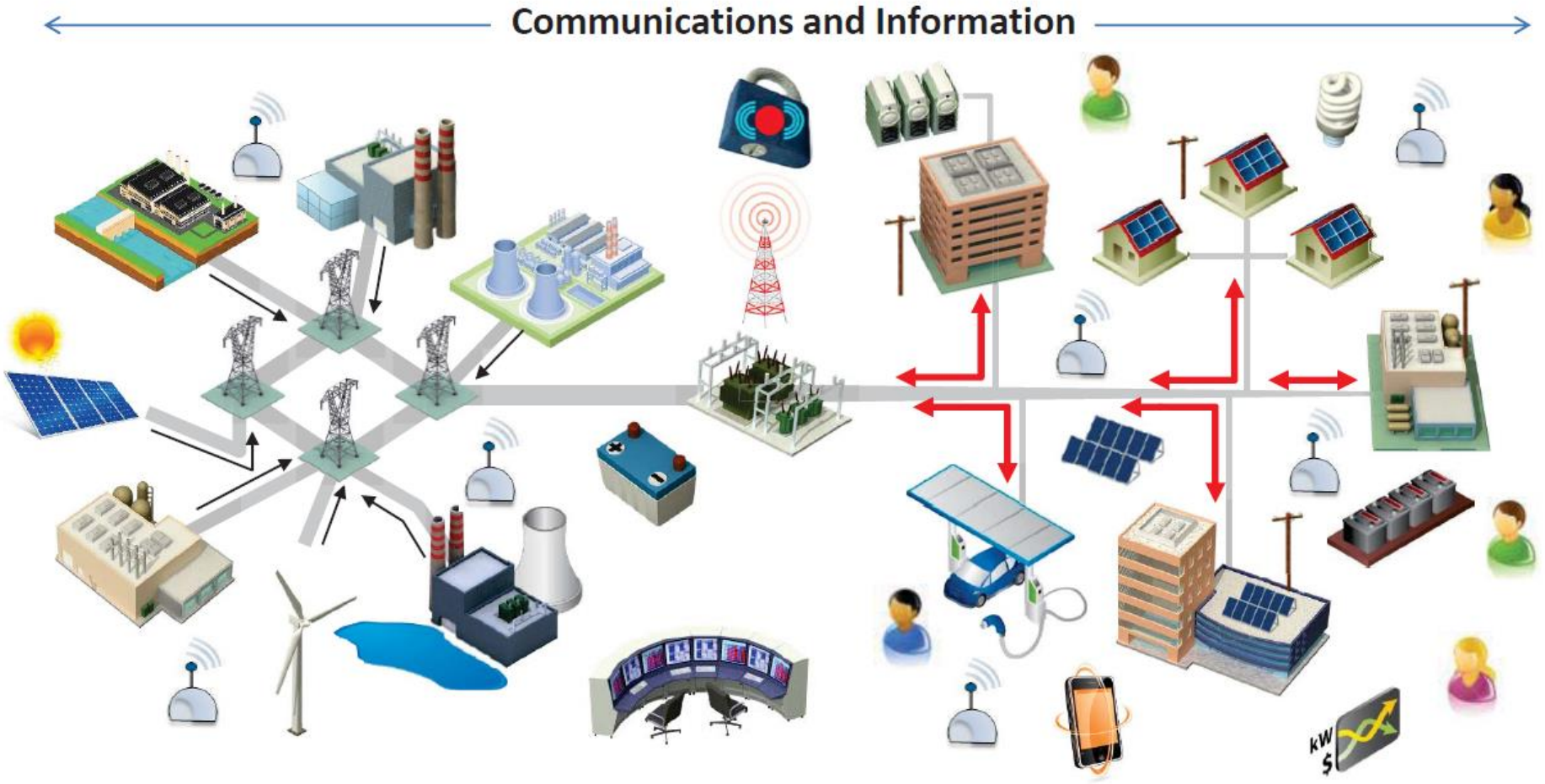
Transforming the US Electric Grid

Today's Electrical System in the United States



Generation Delivery Customer

Future Electrical System in the United States



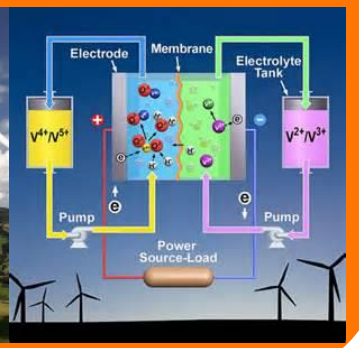
A Highly Interconnected Power System that Optimizes Energy Resources

The Grid of the Future ('Smart Grid') will consist of New Operational, Information and Telecommunication Technologies

Supply ⟷ **Network** ⟷ **Demand**

Traditional Generation (Coal, Gas, Nuclear, Hydro)
Solar
Wind
Biomass
Energy Storage
Geothermal



Challenges:

New technology risks
Minimal Experience
Intermittency
Costs (Financing, Operational)

The Grid of the Future ('Smart Grid') will consist of New Operational, Information and Telecommunication Technologies

Supply ⟷ **Network** ⟷ **Demand**

Operational Technologies (Sensor, Controls)
Telecommunications (wired, wireless)
Software (Information Technology)

Challenges:

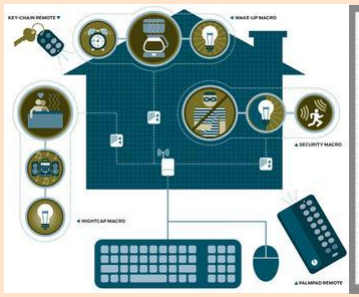
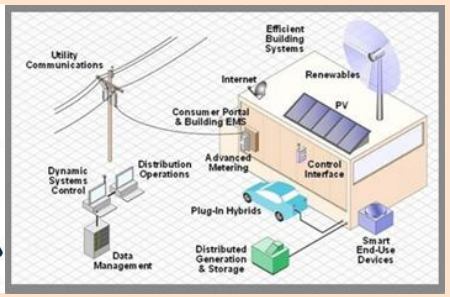
- New technology risks
- Minimal Experience
- Security
- Big Data Management

The Grid of the Future ('Smart Grid') will consist of New Operational, Information and Telecommunication Technologies

Supply ⟷ **Network** ⟷ **Demand**

Smart Meters
Smart Appliances
Local Generation and Storage



Challenges:

New technology risks
Minimal Experience
Security
Entrenched Culture

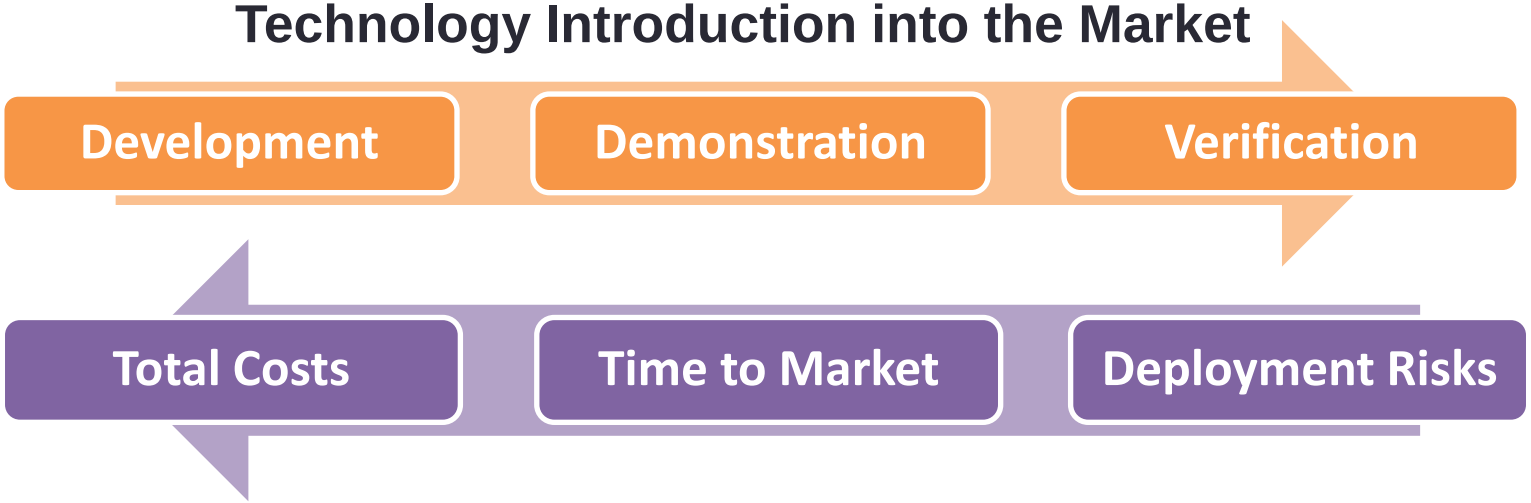
Key Challenges to Modernizing the Grid

- Massive existing infrastructure requires new technologies to be seamlessly integrated into the existing system.
- Existing policies, codes and regulations do not support utility needs to ensure performance of devices during transient conditions.
- Test platforms for new technologies are limited and tend to be on the smaller scale limiting testing of larger multi-megawatt devices.
- Utility operators have had minimal experience operating a bi-directional system.
- New platforms are needed to handle massive data and information to make real-time decisions on system.
- Distributed generators are intermittent and current system is not optimized to handle intermittency.
- Grid security.
- Established culture amongst customers on the use of electrical power.

Modernizing the electrical grid into an energy efficient, reliable and secure network requires:

- new technologies that must play a significant role in power system stability.
- the ability to replicate a complex dynamic system like the electrical grid for testing purposes.
- extensive testing of hardware and software to meet safety and quality assurance requirements through ***'fully integrated'*** system testing.
- parallel model verification and validation of physical hardware to ensure higher reliability and stability once deployed on the electrical grid.

Advanced Testing Lowers the Risks and Costs of New Technology Introduction into the Market



Clemson University through public/private partnership designed and built a grid integration test lab:

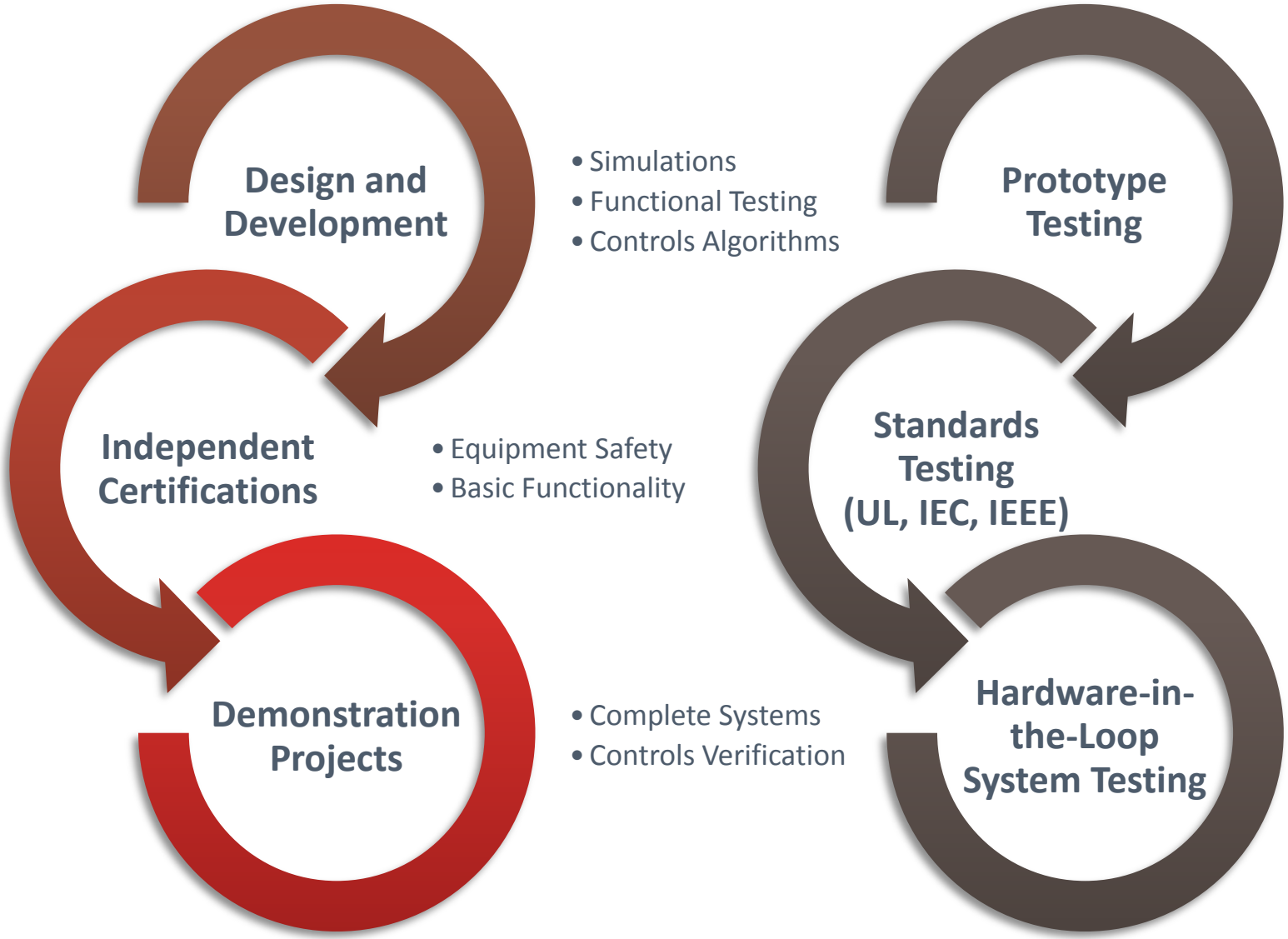
Duke Energy

Electric
Grid
Research
Innovation and
Development

"eGRID is a world-class, 20 MVA utility-scale electric power laboratory combining real time grid simulation capabilities with a highly configurable, multi-megawatt, medium voltage three phase experimental grid."

Public/Private partnership to develop new technologies, accelerate them to the market and educate the workforce of the future.

How the EGRID center fits into the technology development cycle



Grid Integration Studies

Steady State and Envelope Evaluations	• Power Set Points • Voltage and Frequency Variations • Controls Evaluation
Power Quality Evaluations	• Voltage Flicker • Harmonic Evaluations • Anti-Islanding (Software)
Ancillary Services	• Frequency Response • Active Volt-VAR Control • Active Frequency Regulation
Grid Fault Ride-Through Testing	• Low Voltage Ride-Through (LVRT) • Unsymmetrical Fault Ride-Through • High Voltage Ride-Through (HVRT)
Open Loop Testing	• Recreation of field events with captured waveform data
Hardware-In-the-Loop Testing	• Simulated dynamic behavior and interaction between grid and the device under test

How the EGRID can aid in development and demonstration?

- Advanced Hardware-in-the-Loop testing can simulate power system events with full scale devices attached to the simulated power system
  - Distributed control hardware, software and communication elements can be deployed on the simulated power system
    - Cyber attacks, communication losses and equipment disruptions can be evaluated on the distributed control devices integrated with the HIL power system simulations
      - Decrease the risk of new technology introduction.

Tomorrow's Power System: A Smart Grid

Figure Source: EPRI

Thank You

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