

Smart Grid Research from a Utility Perspective

TCIPG Seminar – May 2, 2014
Richard Smith
Director – Research and Development
Ameren Corporation



Outline

- **Introduction**
- **Ameren Overview - A representative U.S. utility**
- **Industry Context**
- **Smart Grid Technology – Business Perspective**
- **Ameren Smart Grid Activities**
- **R&D Needs**

Ameren Overview



A diversified regional electric and gas utility

- 2.4 million electric and 900,000+ gas customers
- 10,300 MW total electric generation capacity
- 64,000 sq. mi. service area
- ~\$9.5 billion equity market capitalization
- Component of S&P 500
- 8,500 Employees

Rate-regulated Operations

Ameren Missouri

- Rate-regulated generation, transmission and delivery business
- Serves 1.2 million electric and 126,000 gas customers
- 2013 native load ~37 million MWh
- 10,300 MW of total generation capacity
- 2013 generation of ~43.2 million MWh

Ameren Illinois

- Rate-regulated transmission and delivery business
- Serves 1.2 million electric and 827,000 gas customers
- 2013 native load ~37 million MWh

Ameren Transmission

- FERC-regulated
- Three MISO-approved multi-value projects totaling >\$1.3 billion (through 2019) at ATXI
- Additional projects totaling ~\$1.0 billion (2013-2017) at Ameren Illinois

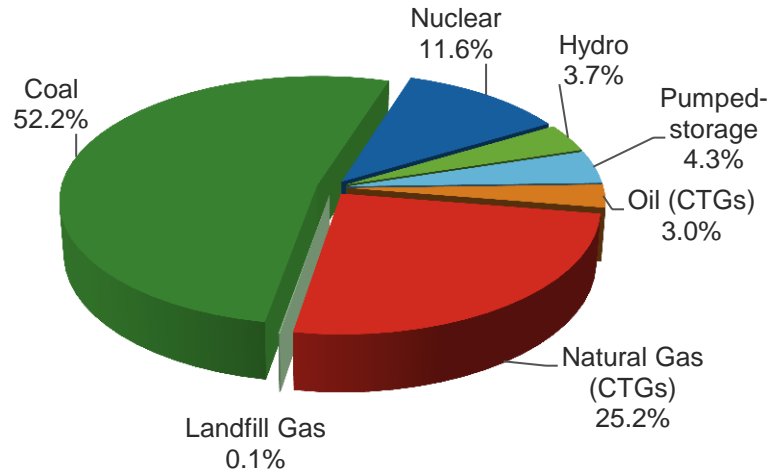
Combined statistics:

Electric transmission lines ~ 7,500 miles
Electric distribution system ~ 79,100 miles
Natural gas system ~ 21,500 miles

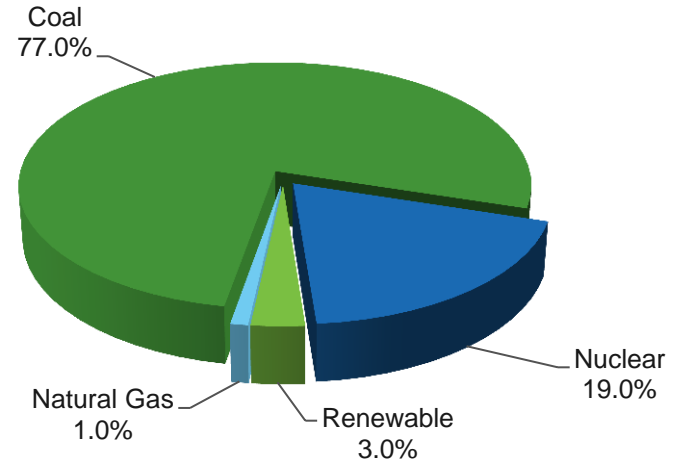


Ameren Missouri Generation Profile¹ - 2013

Capacity ~ 10,300 (MW)



Generation Mix



Generation mix is determined by electricity market economics and dispatch decisions made by RTOs on a daily basis

¹Excludes purchased power

Outline

- Introduction
- Ameren Overview - A representative U.S. utility
- **Industry Context**
- Smart Grid Technology – Business Perspective
- Ameren Smart Grid Activities
- R&D Needs



What Utilities Do.....

- Ownership of state-regulated energy infrastructure assets
- Large scale utility system operations
- Asset management
- Capital management
- Large scale system integration

Our value creation proposition is premised on effectively dealing with the complexities of bringing it all together in a low cost and reliable manner - for our customers

As viewed through the lens of technology advancement



Key Utility Industry Drivers

Capital Markets & Desired Investment Returns

Economic Growth

Environmental Regulations

Government Ideology & Policy

Natural Gas Prices

Reliability

Technology Advancement

KEY
DRIVERS

Customer of the Future

Climate & Environmental Policy

The Future of Coal

Natural Gas

Nuclear

Renewable Energy

The Economy

Power Prices

Transmission

Technology

What are the implications for customers and smart grid?

Achieving Balance – Utility Priorities

Customers and Communities

- Reliable and affordable
- Quality service

Environment

- Cleaner generation and renewable energy
- Reduce environmental impacts

Workforce

- Safe working environment
- Preferred employer

Shareholders

- Predictable returns and earnings growth
- Solid financial management

How does investment in smart grid help with these priorities?



Outline

- Introduction
- Ameren Overview - A representative U.S. utility
- Industry Context
- **Smart Grid Technology – Business Perspective**
- Ameren Smart Grid Activities
- R&D Needs



Potentially Transformative

Technologies that could prove “transformative” to the traditional utility system in the long-term:

NATURAL GAS EXTRACTION

- Fracking and directional drilling
- Recovery of methane hydrates

NUCLEAR

- Small modular nuclear reactors

DISTRIBUTED GENERATION

- Solar technologies
- Energy storage systems
- Small scale natural gas fueled

NONTRADITIONAL ENERGY SYSTEMS

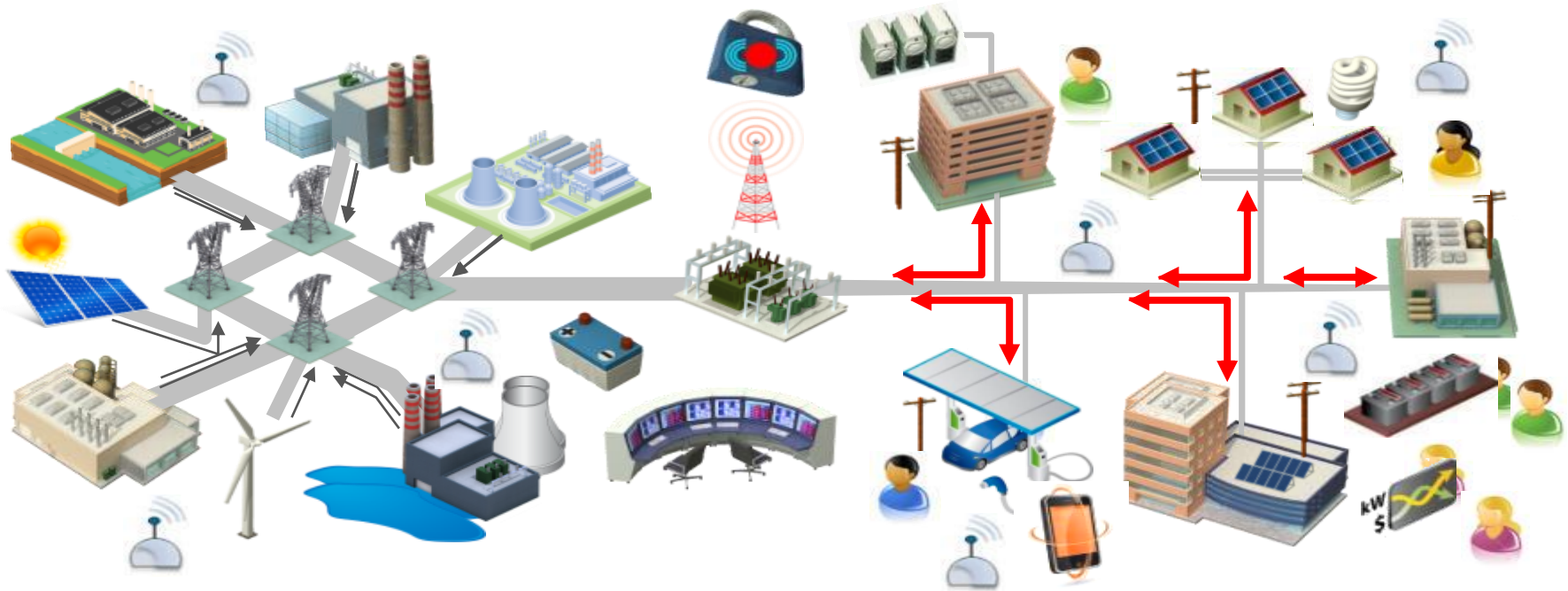
- Microgrids
- Net-zero energy buildings

ADVANCED COMPUTING & GRID AUTOMATION

- Smart grid/analytics
- Automation

← *Technical and Business Case Uncertainties* →

Smart Grid Long Term Vision



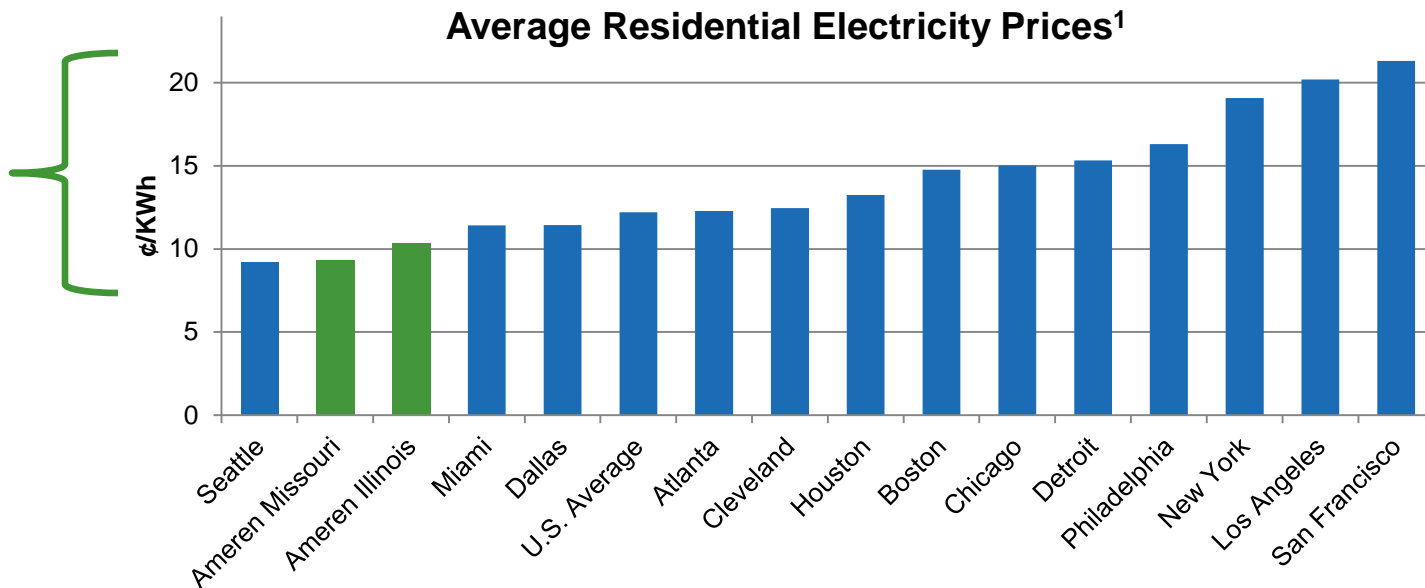
*A Transformed Electrical System that is Highly **Flexible**, **Resilient** and **Connected** and Optimizes Energy Resources - EPRI*

Technological “Grid Parity” = Utility Customer Price

Will a modern “grid” with DER² be price competitive in the future?

What will utility customers be willing to pay?

Price and reliability – the top two customer issues.

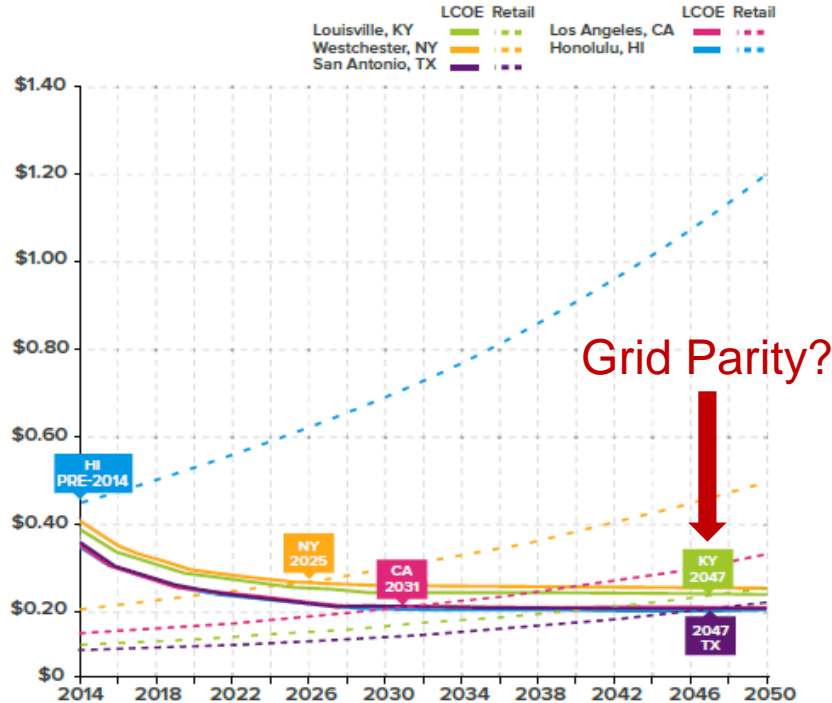


¹ Source: Bureau of Labor Statistics and “2013 EEI Typical Bills and Average Rates” report.

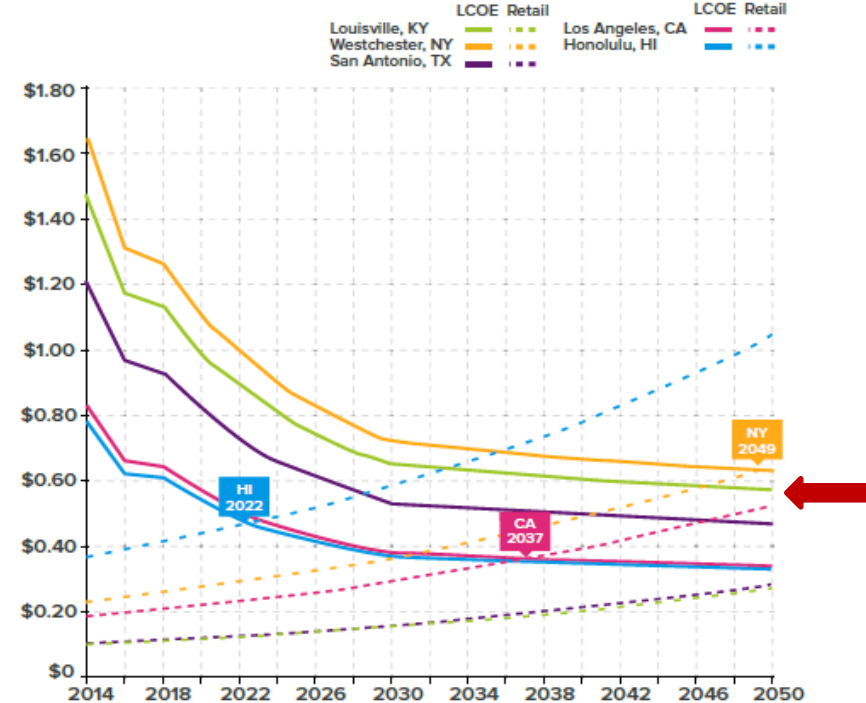
² DER = Distributed Energy Resources, e.g. DG, Community Energy Storage, PV, etc.

Long-term Challenge – e.g. PV with batteries

**FIGURE 1: OFF-GRID VS. UTILITY PRICE PROJECTIONS
COMMERCIAL - BASE CASE**
[Y-AXIS 2012\$/kWh]

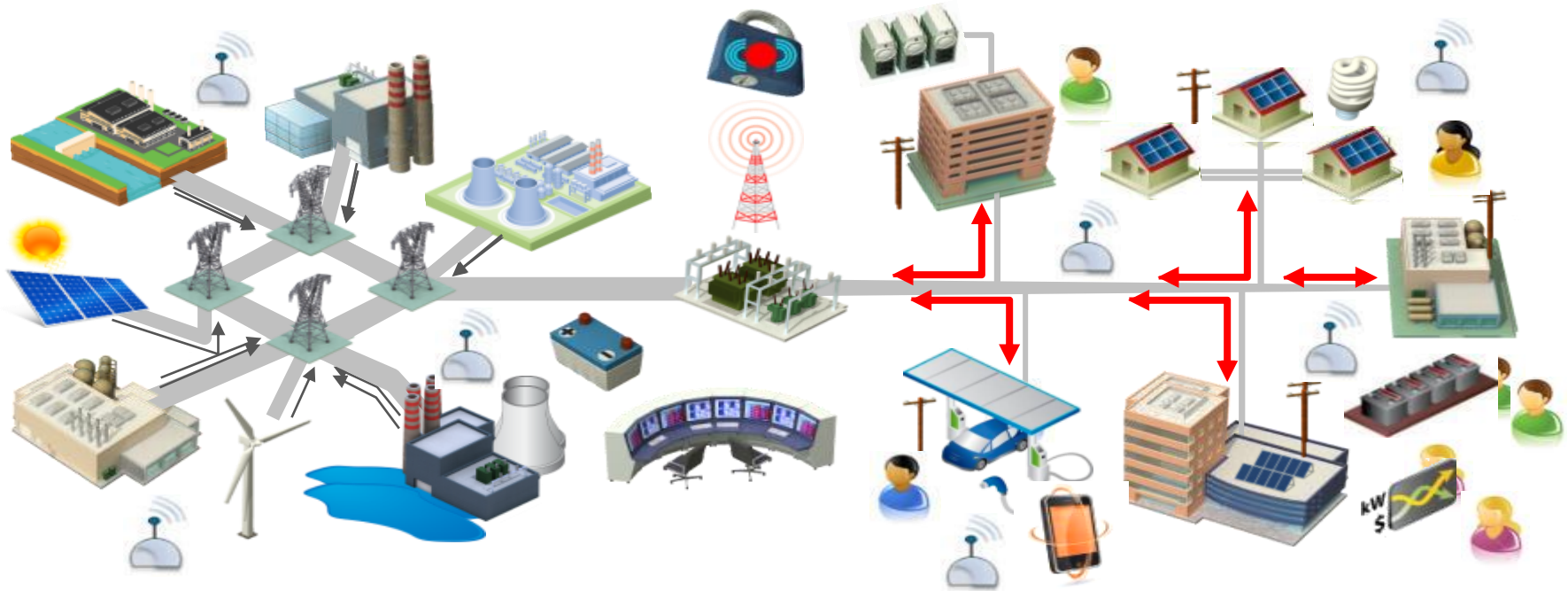


**FIGURE 2: OFF-GRID VS. UTILITY PRICE PROJECTIONS
RESIDENTIAL - BASE CASE**
[Y-AXIS 2012\$/kWh]



Not a near-term opportunity for our customers as a "component technology"

Smart Grid Long Term Vision



How many of these technologies will make sense for deployment in the future?

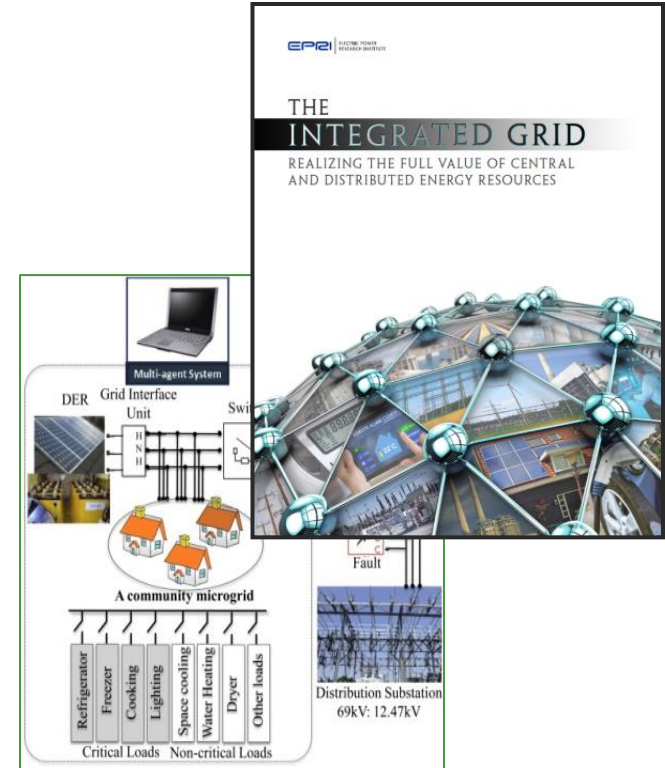
Technology Challenges/Opportunities

- Avalanche of perspectives:
 - Journals, magazines and newsletters related to emergence of all kinds of technologies from generation to delivery, to customer end use. What is real? What has real business value?
- “Hard Trend” - technology is changing
 - With and/or without utilities
 - Which technologies matter? Which ones will be at a scale that matters at reasonable cost?
- Convergence of information, operation, and communication technologies
 - provides an architecture or platform for the future
 - Component technologies improving
 - Need for standards based approaches
- A call for cleaner generation is still being heard
- How can utilities leverage the technologies to benefit customers?



Key Business Questions

- Will smart grid technologies continue to improve and **will costs decline enough?**
- What will be the **pace of technological change** and timing of market development?
- Can investor owned utilities **earn a return** on investing in smart grid and extensions like “community power” systems?
- How should we think about breaking “the grid” into smaller operating segments? (**to what extent a “grid of grids”?**)
- Will smart grid technology applied to the distribution system provide a good platform for greater amounts of **cleaner generation** in the future?
- Will utility **customers** choose to take advantage of emerging technologies?
- What will **regulators** promote or allow in the future?



In the long run, will customers be willing to pay for grid improvements and migration to a more interactive, cleaner operation based on advanced technologies?

Outline

- Introduction
- Ameren Overview - A representative U.S. utility
- Industry Context
- Smart Grid Technology – Business Perspective
- **Ameren Smart Grid Activities**
- R&D Needs



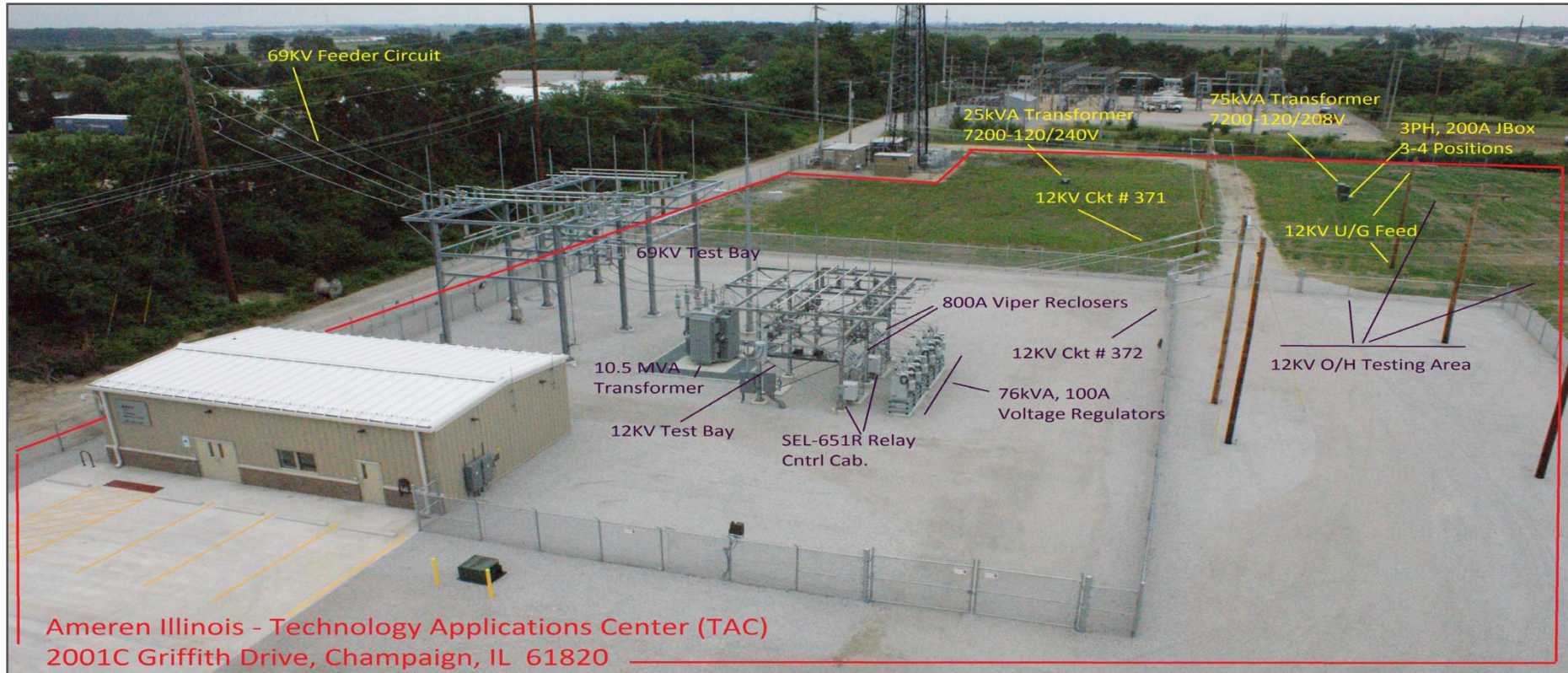
Ameren Smart Grid Related Activity



- AMI (750,000 meter installations in progress)
- Technology Application Center “test bed”
 - Collaboration with University of Illinois
 - On-grid testing and evaluation services
 - Opened for business - August 2013
- Ameren Missouri “test bed” in St. Louis County
- Automated switching, auto cap banks, volt/var control, sensors, PMUs, substation automation
- Advanced Distribution Management System project – Missouri and Illinois
- Plug-in vehicle programs
- EPRI Smart Grid Demonstration member
- CVR Pilot Project at AIC



Technology Application Center



Technology Application Center – Equipment Examples

Testing Equipment Platform



Voltage Regulators



Relay Panels



Smart Appliances



Distribution SCADA Panel

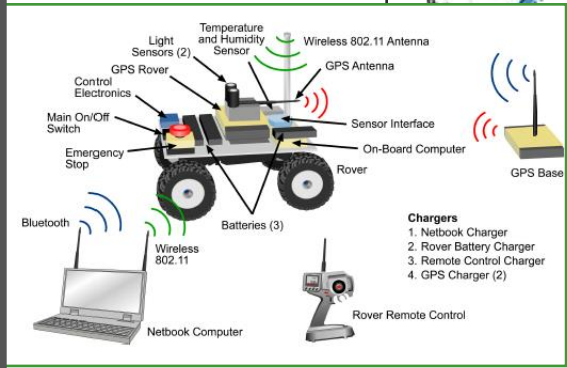
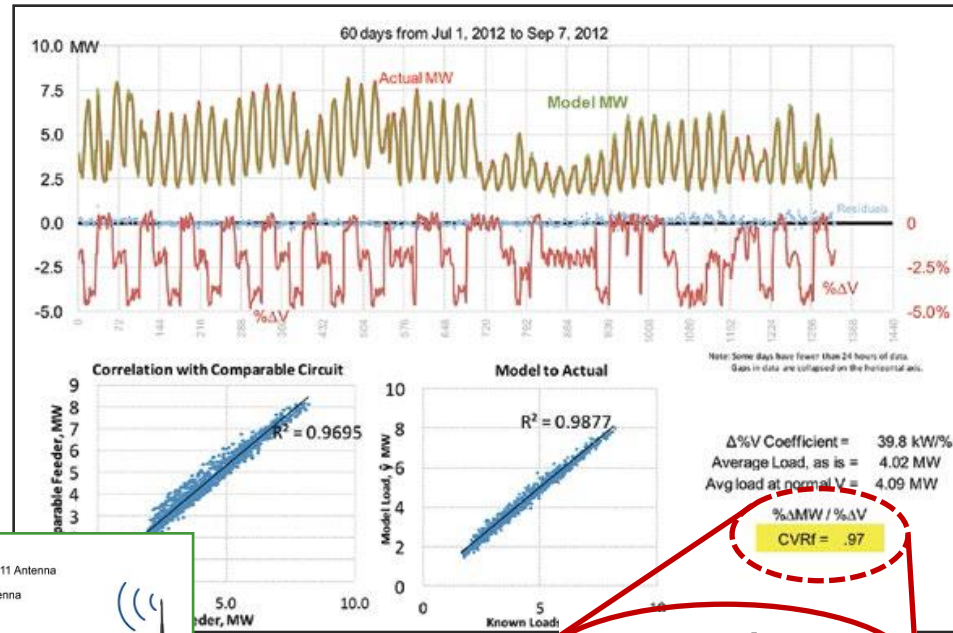


AMI Metering Bank



Selected Ameren R&D Projects

- Participant in EPRI's Smart Grid Demonstration Project Initiative
- Ameren Illinois CVR Pilot
- Energy Efficiency Demo - LED Lighting Ballwin, Missouri



EPRI Rover

$\%MW / \% \Delta V$
 $CVR_f = 0.97$



EPRI smart grid updates available at:

www.epri.com

Ameren Microgrid, DG Pilot Projects



Missouri S&T Solar Village Microgrid Project

- Rooftop Solar PV
- A123 Li-ion Battery System
- ClearEdge 5kW Fuel Cell (community power)



ClearEdge 5 kW Unit

- Lewis & Clark Community College



3 MW Brookside Substation Fuel Cell Demo Project – Delmarva/EPRI

A New Model

<p>Information Revolution</p>	<p>Distributed, personalized technology unleashed a wave of...</p> <ul style="list-style-type: none"> • Creativity • Business productivity • Innovation
<p>Energy Infrastructure Transformation</p>	<p>Personalized Energy</p> <ul style="list-style-type: none"> • Distributed • Flexible • Efficient • Reliable • Affordable • Upgradable • Clean



Outline

- Introduction
- Ameren Overview - A representative U.S. utility
- Industry Context
- Smart Grid Technology – Business Perspective
- Ameren Smart Grid Activities
- **R&D Needs**



Currently Available Technology is Enabling:

Sensors	Automation	Applications
Transformers: <ul style="list-style-type: none"> • Bushings • Temperature • Dissolved gasses 	Remote Voltage Regulator Control	Conservation Voltage Reduction <ul style="list-style-type: none"> • How to prioritize circuits for CVR deployment
Electric Distribution Lines: <ul style="list-style-type: none"> • Faulted circuit indicators • Remote voltage 	Remote Capacitor Control	Software <ul style="list-style-type: none"> • Software defined networking • Intrusion detection
Relays (sense, control, some diagnostics)	Remotely Operated or Automated Switches	Automated: <ul style="list-style-type: none"> • Circuit isolation • Switching • Fault locating
	AMI with multiple functionalities: <ul style="list-style-type: none"> • Read • Connect and disconnect • Voltage • Theft detection, etc. 	Distributed Resources: <ul style="list-style-type: none"> • Some degree of control and coordination of DR • System operating with some distributed generation



Needed Technology Improvements:

Communications	Automation	Data Analytics
Systems need to link devices	Real time control systems	Manage data from growing number of AMI installations
Common Information Model	Advanced algorithms for control actions	Manage data from sensors and provide: <ul style="list-style-type: none"> • Actionable information • System awareness / state visibility Improve outage information and restoration from storms and disasters
Trustworthy and cyber secure	Coordinate and control higher levels of distributed generation: <ul style="list-style-type: none"> • Control voltage and frequency with high levels of low-inertia generation, e.g. solar PV • Maintain or improve reliability for the customers 	Provide a “health of the system” model: <ul style="list-style-type: none"> • Insights for planned maintenance • Anticipate operating needs • Inform business planning and investment priorities Inform the case for regulatory improvements to support grid modernization



Potential Additional Research Priorities

Customer	Distributed Generation	Communications
Smart Grid Enabled Products and Services	Value of Grid Connection to Distributed Generation	Optimal Communications Approach <ul style="list-style-type: none"> • Cyber secure • Fiber vs. wireless • Long term view
Value of Grid Connected Services	Techno-economics of Small Scale, Cleaner Generation Connected to Distribution Systems	Standards Based Approaches to Smart Grid Device and System Deployment
Cyber and Physical Security of Grid Interactive Customer Systems	Techno-economics of Energy Storage <ul style="list-style-type: none"> • Time to Market for Cost-Effective Options 	Automated: <ul style="list-style-type: none"> • Circuit isolation • Switching • Fault locating
Customer Interest in Emerging and Future Smart Grid Related Technologies	Potential for Natural Gas Generation and Adoption of Solar PV	Distributed Resources: <ul style="list-style-type: none"> • Some degree of control and coordination of DR • System operating with some distributed generation



Microgrids – Key Research Needs

- Develop the underlying theory of microgrid technology
 - Optimum scale
 - Balance - load, storage, generation, and advanced automation
 - Reliability - low inertia generation-load-storage system
 - Scale-ability
 - Customer experience
 - Cost
- Technology improvements - necessary and feasible to enable broader, economically efficient deployment?
- Technical basis – to optimize utility business models
- Cost – capital and O&M

A techno-economic study of the current and expected future states of microgrids is needed to provide insights for research directions and potential investment opportunities for utilities and our customers

Conclusions

- It is the **system** that matters the most – from generation to transmission to distribution **with** the customer
- The “smart grid” will look more and more like an IT or ICT **architecture** over time – **convergence** of ICT with OT (operational technology)
- The emerging “grid” **system** will enable **component technologies**: e.g. PV, energy storage, and fuel cells - along with “community power” and customer power systems
- Advancement of technologies **will** continue
- There will be continually increasing levels of grid automation over time:
 - Moore’s Law is alive and well
 - Includes greater interactivity and integrated operations with the customer – cyber?
- **Efficiency improvement** opportunities greater in end-use – not grid
- Smart grid research needs to address the key business questions



Contact info:

Richard Smith

Office: 314.554.3531

email: rsmith3@ameren.com

Technology Application Center:

Rod Hilburn

Office: 217.424.6638

email: rhilburn@ameren.com



Ameren

FOCUSED ENERGY. For life.