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The Future Electric Grid

Charles Hanley

Solar Systems Department, 6335

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NNSA National Nuclear Security Administration

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The Origins of This Presentation

- Sandia is investigating and developing new “Grid Integration” technologies for DOE/Solar program
- Includes advanced inverters, controllers, energy management systems
- DOE to conduct an industry solicitation this fall - $6-8 million annually for three years (SNL technical management)
- DOE/Solar also leading several studies related to the impact of high penetration of renewable energy on the electrical grid – links to other DOE future grid programs.
- These studies could lead to a new initiative of several $100 million – potentially a new DOE program office – to address grid modernization issues.
- In May, 2007, Sandia (Ward Bower) conducted an Advanced Energy Managements Systems technical workshop
  - Most of the following material was presented at this workshop.

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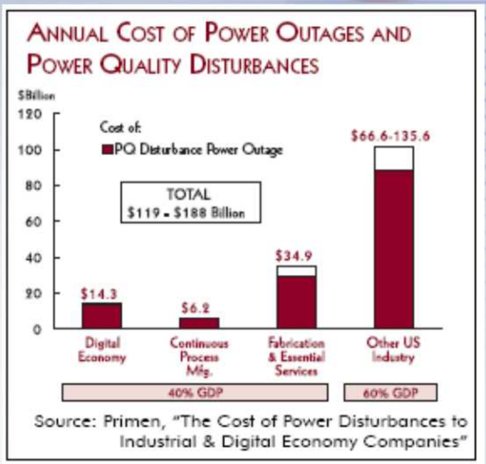
Some of the fundamentals: the need for a new electric delivery paradigm



- Current grid enabled the mechanical industrial revolution, but is not fit for digital times (Bob Galvin)
- Economics:
  - Electricity lost over power lines has doubled since 1980 – estimated at $12 Billion annually
  - Every day 500,000 people in U.S. go without power for at least 2 hours – cost estimated at $150 Billion annually (Galvin, EPRI)
- Carbon and pollution issues: electric generation industry is one of the dirtiest in the U.S.
  - 39% of carbon (climate change)
  - 33% of mercury (health)
  - 63% of sulfur dioxide (acid rain)
  - 22% of nitrus oxide (smog)
- Back to economics:
  - Estimated benefits of new technologies and businesses in 2020: $40-60 Billion annually
  - Many U.S. companies developing business models and products

(Source: www.galvinpower.org)

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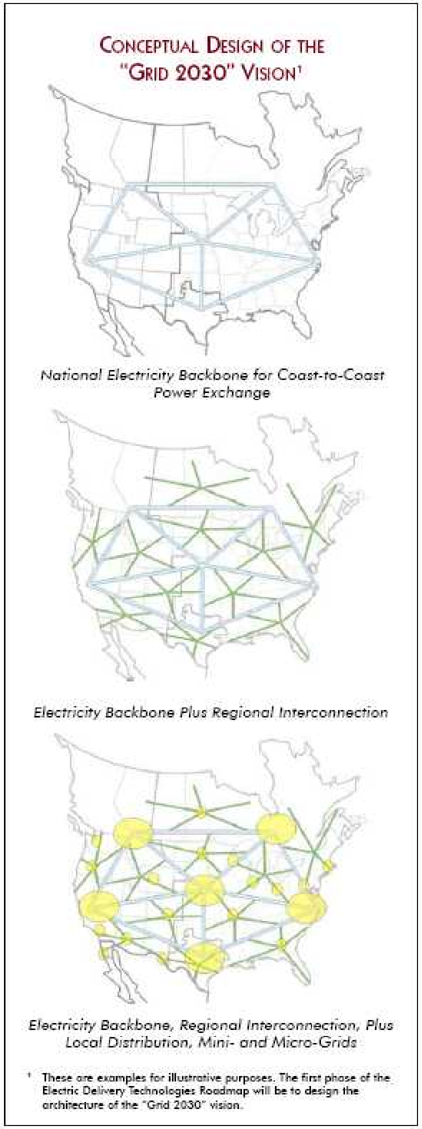
Factors affecting the future of our electric system



- Public Policy Drivers
  - Electric sector restructuring
  - Environmental regulations
  - National security
- Market Drivers
  - Competition
  - Aging infrastructure
  - Consumer demands
- Technology Drivers
  - Information technologies
  - New materials
  - High temperature superconductors
  - Energy storage
  - Advanced power electronics
  - Distributed energy technologies

Source:"Grid 2030 – A National Vision for Electricity's Second 100 Years"

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Slide 4

s1 under Technology Drivers

*electricity storage- should be energy storage

sgonza, 10/3/2007

Many R&D programs working to define future electric grid

- Intelligrid
- Modern Grid Initiative
- GridWise
- Advanced Grid Applications Consortium
- Power Systems Engineering Research Center
- Consortium for Electric Reliability Technology Solutions
- California Energy Commission
- New York State Energy R&D Authority
- European Union 5th and 6th Framework Programs
- Galvin Electricity Initiative

(Source: EPRI Technical Report "Profiling and Mapping of Intelligent Grid R&D Programs")

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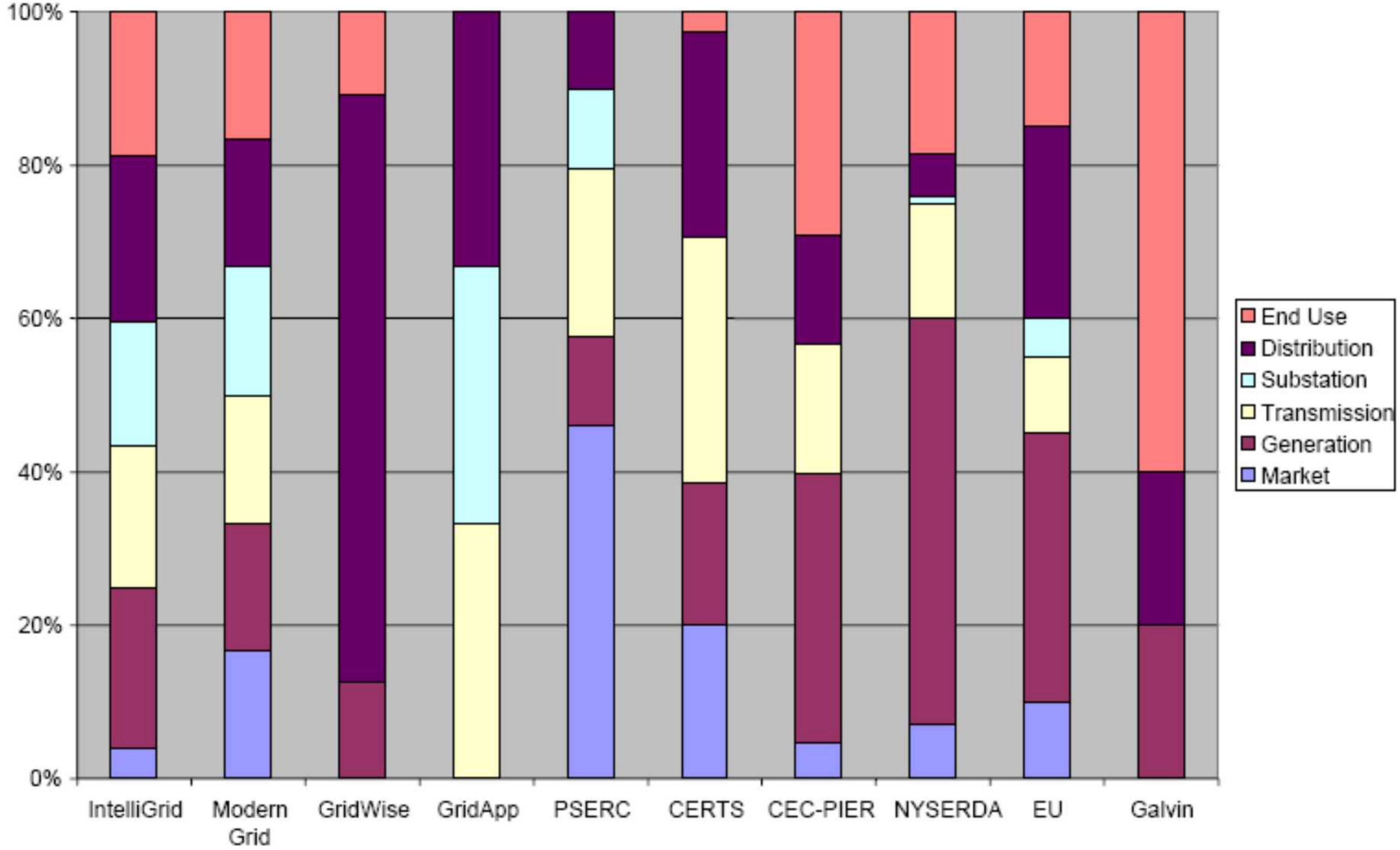
EPRI report shows much effort going into end use, distribution, and generation

Relative research efforts of each program by sector of application (based on budget):



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Some common themes exist among these intelligent grid programs

- Relaxing transmission congestion through distributed generation
- Distributed controls
- Communications
- Use of storage
- Intelligent loads/load management
- Need for field implementations, monitoring, real data

Many grid issues are solved through distributed generation, but…

Several real-world examples demonstrate limits to what the grid can handle:

- Tucson Electric Power – cloud-induced transients at Springerville PV plant force oscillations in Auto Generation Control (AGC) of coal plant
- Italian blackout of 2003 – exacerbated by high levels of DG penetration
- European Simulation Studies – voltage fluctuations with high PV penetrations in different network configurations
- GE study for NREL (2003) – various simulations showing negative impacts (i.e., excessive DG tripping) of high penetration
- Other relevant, real world examples?

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A slightly more technical cut at the issues of high-penetration DG

- Addressed in standards (i.e., IEEE1547)
  - Inadvertent Islanding
  - Primary System Neutral Grounding
  - Interference with Utility Voltage Regulation
  - Harmonic Interference

- Not addressed in standards
  - DR Protection and Control Reliability
  - DR Fault Current Contribution
  - Load Flow and Voltage Margin Studies
  - DR Effects on Feeder Reliability
  - Emergency and Maintenance Switching Studies
  - Line Voltage Regulator Interaction
  - Protection Effects on DR Reliability
  - System Penetration: Dispatchability and Frequency Support

(Source: John Stevens, SNL; and Douglas Dawson)

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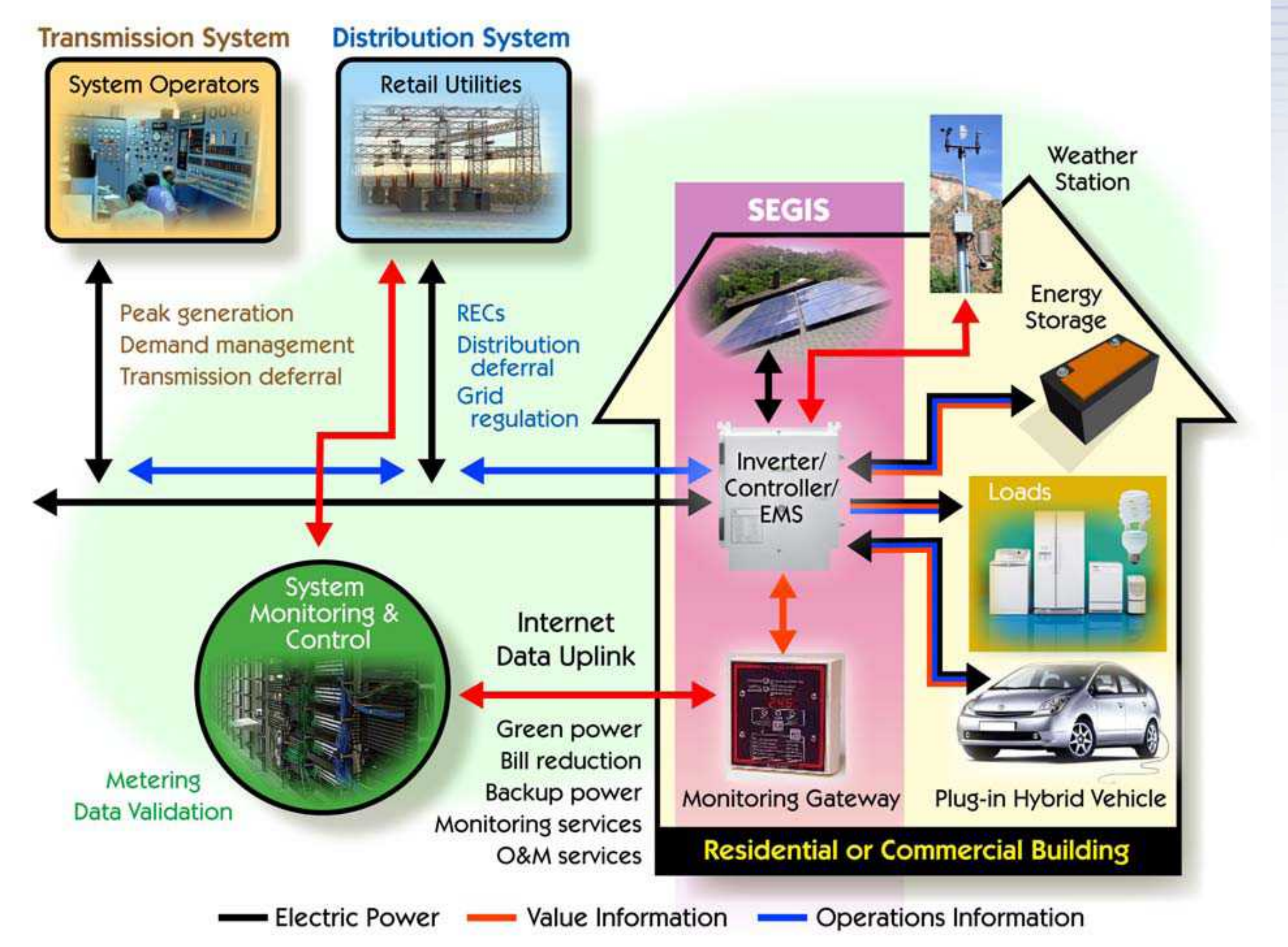
Smart DG systems of the future will interact with a smart grid



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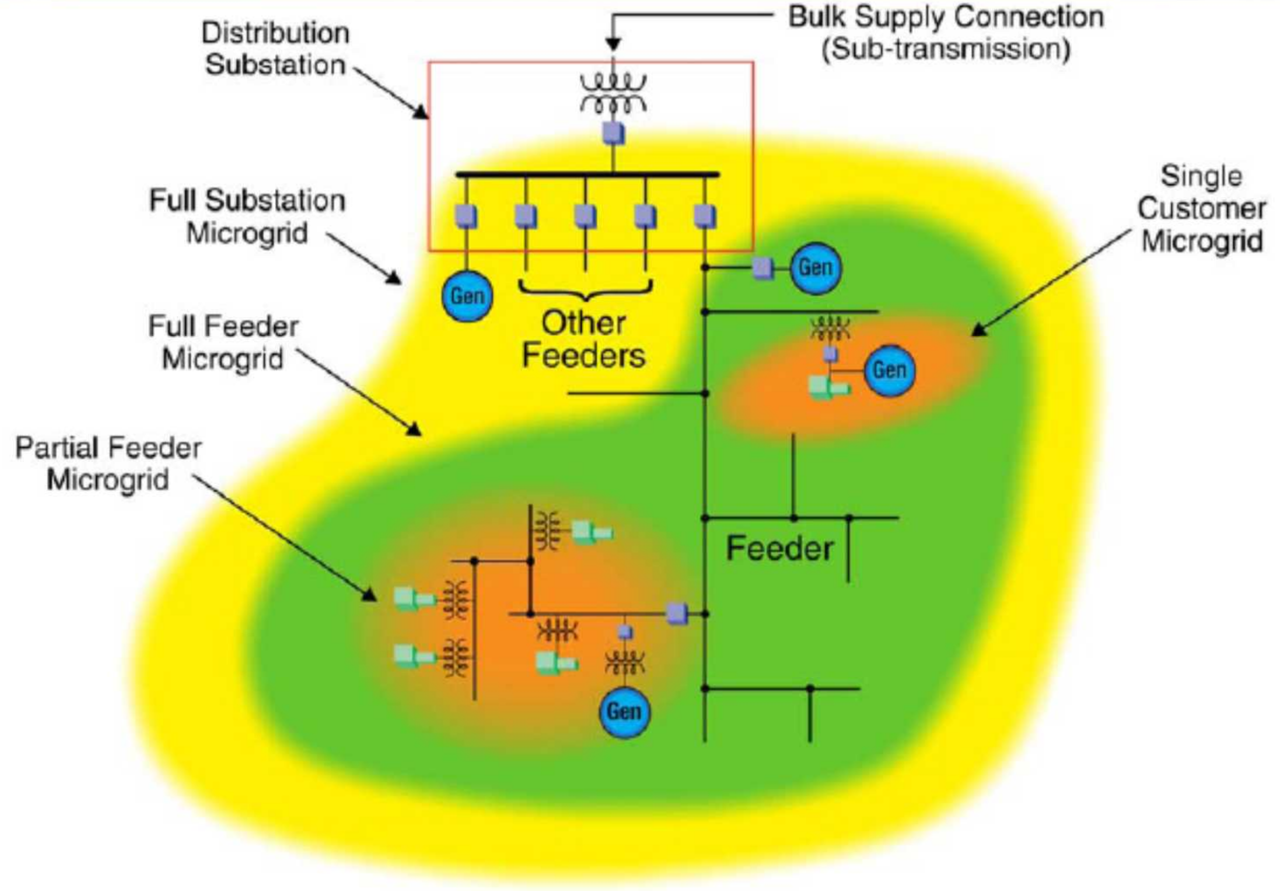
The future distribution grid will be comprised of integrated microgrids



Source: Electric Power Research Institute

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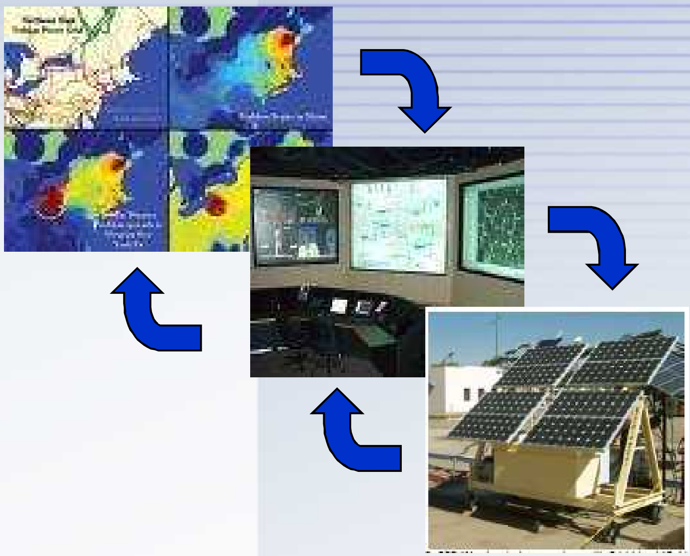
DOE-proposed effort
Solar-Grid Integration: Meeting New Needs

Problem: To facilitate broad deployment of PV while mitigating grid reliability impacts of transient loads and grid frequency/voltage fluctuation, we must:



Develop Solutions for Utilities:

- Conduct detailed analysis of grid effects and requirements through T&D simulation
- Establish grid infrastructure for localized wide-area energy networks, including utility load/production control methodologies
- Utilize prototype testbeds to evaluate characteristics of new PV systems for grid

Make PV Easier for Utilities to Manage:

- Improve stand-alone capabilities of PV systems with marginal storage
- Develop utility-interactive controls for distributed PV installations

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Several areas of Sandia work are contributing to the future grid

- Energy surety microgrid development – being applied on military bases
- Mesa del Sol – sustainable community development south of ABQ airport
- Hawaii: Kauai Test Facility – high energy costs and low reliability create a need for new solutions
- Advanced inverter and energy management systems R&D
- LDRD: microgrid controls
- Secure Supervisory Control and Data Acquisition (SCADA)
- Storage program – large-scale pilot implementations
- Nanosciences: storage, controls, embedded sensing on generators (i.e., PV)
- New superconducting and insulating materials to reduce losses in transmission

Some further considerations

These points came from the May workshop – I leave them here to stress their importance:

- STORAGE IS KEY
  - Bill Henry (TEP): improve power factor versatility of inverters; need for PV version of "spinning reserve"
  - Chris Cameron (SNL): improve economics to system owner
  - Juan de Bedout (GE): improve reliability at the home; value to the community

- Hanley: in a fully optimized system, generation = use at all levels of generation: home, community, utility, etc. (again: storage is key)

- Enhanced communications will bring new information security needs