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POWER SYSTEM INTERCONNECTION FOR DISTRIBUTED ENERGY

ENG 300 Energy Surety Presentation

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
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Advantages of Distributed Energy

- **Reduces transmission line loading during peak hours**
- **Offers greater reliability of service.**
- **Requires smaller capital investment for new generation capacity.**
- **Adds generation capacity closely tracks the incremental load growth.**
- **Introduces a time and location specific valuation of delivered energy into utility rates.**

For a 30-point "benefits" list, see Lovins, A., Datta, K. and T. Feiler, A. Lehmann, K. Rabago, J. Swisher, K. Wicker, 2002. *Small is Profitable: The Hidden Economic Benefits of Making Electrical Resources the Right Size*. Rocky Mountain Institute, Snowmass, Colorado.

High Level Issues of DE

- **Regulations, rules, and standards (State and federal jurisdictions gaps and overlaps can be confusing.)**

- **Rates and tariffs (economic barriers)**

- **Interconnection to the power grid**

- FERC-Transmission interconnection and off take contracts
- State – power plant & transmission line siting/permitting, etc.

Source: Tyler Borders, PNNL; US DOE 2/2007

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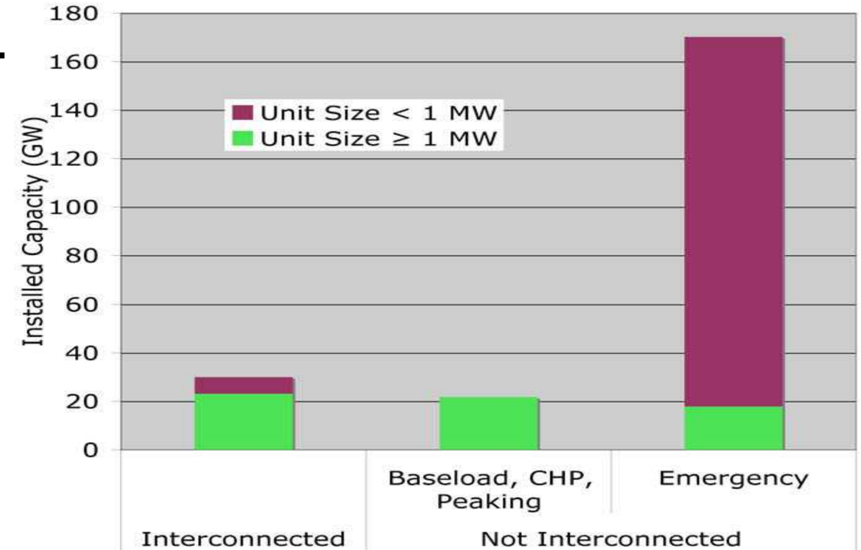
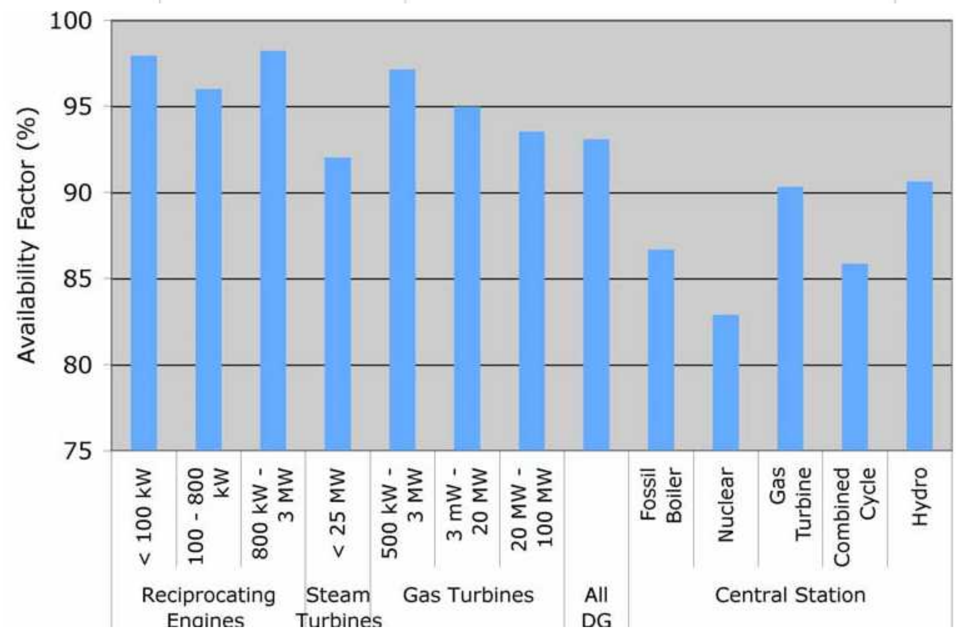
What is Interconnection and Who Cares

- **Interconnection is the linking of on-site generation to the local electric utility's distribution grid.**

- **Many industrial groups believe that grid interconnection is the most significant barrier to Distributed Energy.**
  - **What are old and new problems/solutions?**
  - **What is the current external state-of-the-art?**
  - **What are Sandia's strengths?**
  - **Our recommendations**



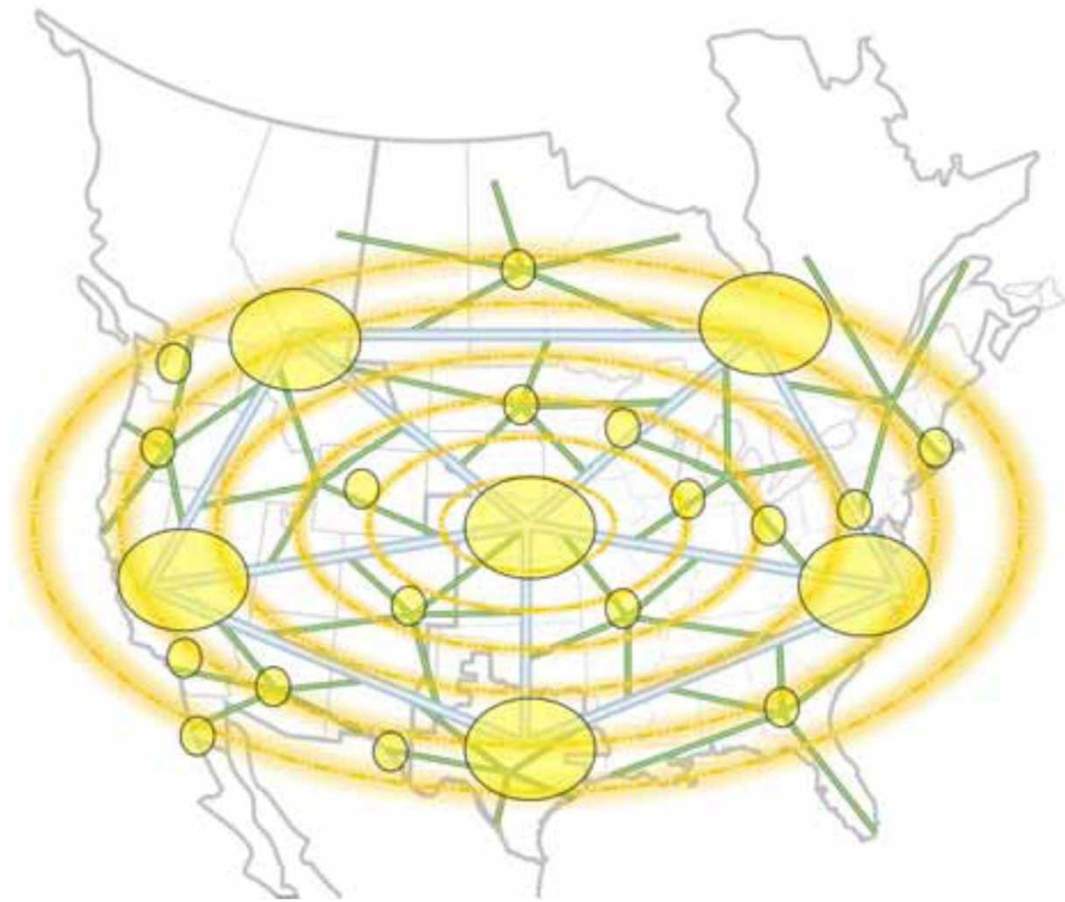


Traditional Interconnection Problems and Solutions
Mathematical Models

- Steady state – Load Flow (Capacity)
- Quasi-steady state – Short Circuit (Fault Protection)
- Dynamic – Operating Limits (Stability)
- Transient – Simulate Realistic Conditions (Reliability)

New Interconnection Problems

- Complexity
- Economics
- Efficiency
- Exchanges
- Environmental/Social
- Security



National Grid 2030

New Interconnection Solutions

- System Integration of Traditional and New Models (Complexity)
- Incorporate Costs and Rates (Economics)
- Infrastructure Management (Aging Infrastructure)
- Utilize New Models for Sources of DG Power (Efficiency)
- Credits for Offsetting Infrastructure Needs (Environmental/Social Impacts)
- Access Control Systems (Security)

The Big Open Questions

How can solutions be implemented in a way that

- **Supports interoperability from transmission to generation, distribution, and users?**
- **Accelerates the transformation of the DE grid into an intelligent and sustainable network?**
- **Optimizes efficiency while preserving safety, security, and reliability…all in the presence of policy and economic constraints?**
- **Ensures that the system is robust to uncertainties and fluctuations?**

Proposed Approach: Use Systems Models to Explore the Possibilities

- **JADE-bases Multi-agent Technology**
  - **Software simulation of a fully distributed, scalable, and robust application of multi-agent technology to coordinate DE systems.**

- **PIER project by AESC for CEC**
  - **Successfully demonstrated how a prototype network of intelligent software agents (*Smart**DER), communicating over the Internet and operating without direct human intervention can coordinate and schedule one or more distributed energy resources.**

- **EPRI IntelliGrid Partnering to Overcome Barriers**
  - **To accelerate the transformation of the power delivery infrastructure into the intelligent grid needed to support the future needs of society**

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Future Modeling Needs

- Data architecture that supports interoperability from transmission to generation, distribution, and users (e.g. really need plug and play)
- Infrastructure that allows rapid development/incorporation of technology models to accelerate the transformation of the DE grid into an intelligent and sustainable network
- Ability to span scales (e.g., national to regional to mini-grid to micro-grid, etc.) in a way that can accommodate a large number of model entities
- More comprehensive system-level view
- Validation (need to ensure reliability predictions for DG models are accurate and credible)

Overall Recommendation

- **Develop a national model of the power distribution system to allow studies of interconnection of distributed energy.**
  - **Opportunity for Stewardship Transformation**
  - **Complementary to NW/Non-Proliferation Work**
  - **National Surety Application**

Recommended Sandia Role 1: System Integration

- Utilize existing expertise at Sandia for system integration, energy, modeling, and analysis
  - 6300 Energy, Resources and Systems Analysis
  - 8100 Homeland Security and Defense Systems

- Partner with other national labs and organizations
  - National Renewable Energy Lab (NREL)
  - Electric Power Research Institute (EPRI)
  - Lawrence Berkley National Lab (LBL)
  - Google

Recommended Sandia Role 2: Spanning Scales in an Extensible Manner

- **Utilize Sandia-developed mathematical tools and associated methodologies to guide model development and validation as well as model-based analyses**
  - **8900 Computer Sciences and Information Technologies**
  - **1400 Computation, Computers, Information, and Mathematics**

- **Partner with universities for development of fundamental mathematical algorithms that support complex systems analysis**

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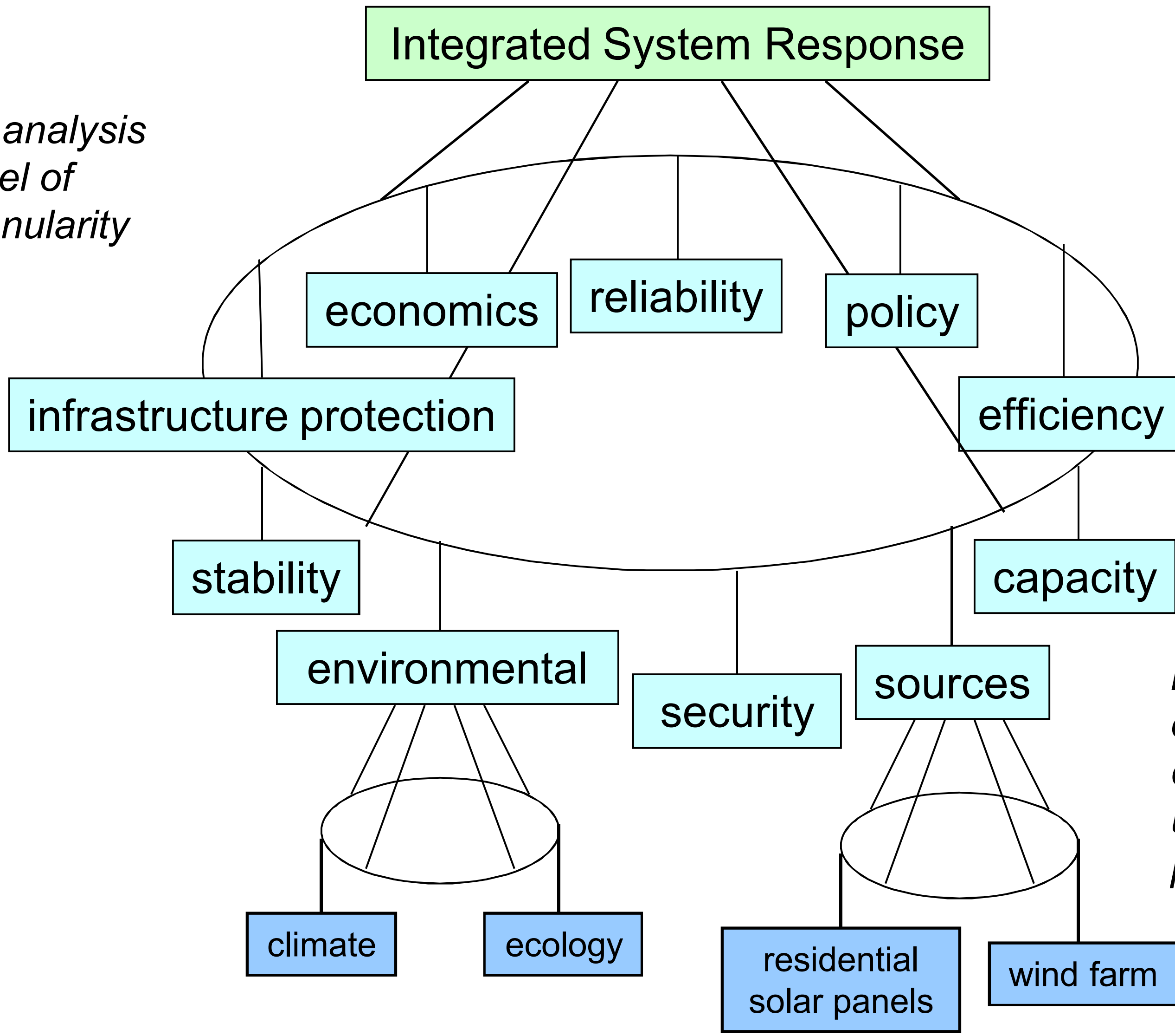
Power Distribution System Model Concept

sensitivity analysis guides level of fidelity/granularity needed



multi-disciplinary optimization combines competing objectives; uncertainty propagation

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Key Aspects of Proposed Model

- **Take a hierarchical approach**
- **Use sensitivity analysis to guide level of model fidelity/granularity needed at each level of the hierarchy and to conduct trade-off studies**
- **Use multi-disciplinary optimization to combine competing objectives across the subsystems**
- **Use uncertainty quantification techniques to evaluate robustness of system being studied**
- **Ideally, embed optimization/sensitivity/uncertainty techniques in the model in such a way that it is all self-updating when new model entities are introduced**

Summary

- Implementing distributed energy systems poses many challenges
- Interconnection to the grid is viewed by many as the biggest of these challenges
- We propose a national model of the power distribution system to allow exploration of issues related to interconnection of distributed energy
- There are identifiable opportunities for Sandia participation that complement more general stewardship transformation efforts

References

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- R. Lum, D. B. Kotak, and W. A. Gruver, "Multi-Agent Coordination of Distributed Energy Systems." *Proc. of the 2005 IEEE International Conference on Systems, Man, and Cybernetics*, Big Island, Hawaii, USA, October 2005.

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- Intelligent Software Agents for Control and Scheduling of Distributed Generation , Publication Number: 600-01-010
  Publication Date: March 2001, http://www.energy.ca.gov/pier/final_project_reports/600-01-010.html

Benefits of DG System (Lovins et al)

1. Shorter construction times
2. Reduced financial risk of over- or under-building
3. Reduced project cost-of-capital over time due to better alignment of incremental demand and supply
4. Lower local impacts of smaller units may qualify for streamlined permitting or exempted permitting processes, reducing fixed costs per kW
5. Significantly reduced exposure to technology obsolescence
6. Local job creation for manufacturing, technician installers/operators
7. Higher local, small-business development and taxes vs. overseas manufacturing
8. Lower unit-cost, automated manufacturing processes shared with other mass-production enterprises (i.e., automotive industry)
9. Shorter lead times reduce risk of exposure to changes in regulatory climate
10. Significant reduction in fuel disruption risk (portfolio of locally produced fuels and “fuel-less” technologies—solar, wind)
11. Reduced fuel-forward price risk
12. Reduced trapped equity
13. Reduced exposure to interest-rate fluctuations
14. Potential for more modular, routine analysis for capital expansions
15. Multiple off ramps for discontinued projects, without same level of risk
16. Ability to redeploy portable resources as demand profiles change
17. Portability = Higher capacity utilization
18. Reduced site remediation costs after decommissioning
19. Higher system efficiency reduces ratio of fixed-to-variable costs (fuel)
20. Potential for lower unit costs for replacement parts when mass produced
21. Displaces that portion of customer load with highest line losses
22. Displaces that portion of customer load with greatest reactive power requirements
23. Displaces that portion of customer load with highest marginal energy costs
24. Weather-related (solar, wind) interruptions more easily predicted and of shorter duration than equipment failures at central plants
25. “Hot swap” capability – when one DG module (panel, tracker, inverter, turbine) is unavailable, all other modules continue operating
26. Load siting reduces or eliminates line losses on electric transmission and distribution lines
27. Inherently improved system stability due to multiplicity of inputs
28. Reduced regional consequences of system failure
29. Improved transmission and distribution reliability due to reduced peak loading, conductor and transformer cooling
30. Fast ramping within the distribution system, ability to reduce harmonic distortions at customer’s site.