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Structuring the Smart Grid Framework: Application of Complex Systems Engineering

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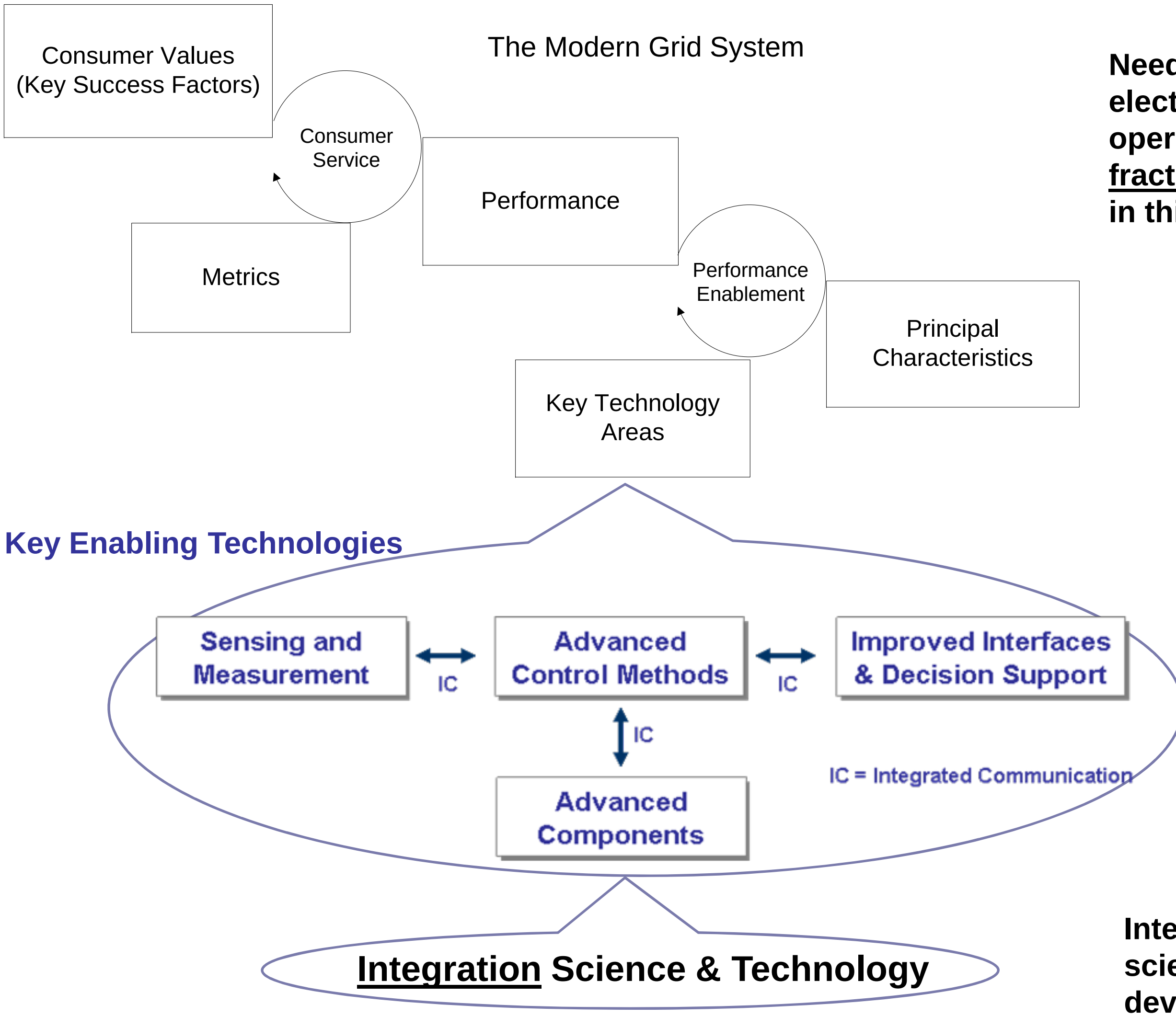
Modern Grid Strategy Team's Role

Mission – Accelerate the modernization of the Grid in the U.S.

- Develop a vision for the Smart Grid using a "systems approach"
- Reach out to stakeholders to get input and consensus
- Assist in the identification and resolution issues
- Promote testing of integrated suites of technologies
- Communicate concepts to assist interested stakeholders

Act as an "independent broker"

Smart Grid Visioning – A Systems Approach



Needed leadership in the electricity delivery vision and operating model; <u>industry too fractured</u> to form a consensus in this area

Traditional focus is in the technology development arena; this area is mature in assuring technology streams

Integration – gap in today's science and technology development

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Principal Characteristics

The Smart Grid is "transactive" and will:

- *Enable* active participation by consumers
- *Accommodate* all generation and storage options
- *Enable* new products, services, and markets
- *Provide* power quality for the digital economy
- *Optimize* asset utilization and operate efficiently
- *Anticipate & respond* to system disturbances (self-heal)
- *Operate* resiliently against attack and natural disaster

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Some Benefits

Utility Operational Benefits

Operational improvements

- *Metering and billing*
- *Outage management*
- *Process improvement*
- *Work force management*
- *Reduced losses (energy)*
- *Asset utilization*

Asset Management improvements

- *System planning*
- *Maintenance practices*
- *Engineering*

These benefits are expected to improve customer satisfaction and reduce O&M and capital costs.

Individual Consumer Benefits

- **Improved reliability**
- **Improved overall level of service**
- **Access to information**
- **Ability to manage energy consumption**
- **Option to participate in demand response**
- **Convenient interconnection of distributed generation**
- **Option to bid (sell) into electricity markets**
- **Potential to dramatically reduce transportation costs (PHEV)**

Consumers have access to information, control, and options

Societal Benefits

- **Downward pressure on electricity prices** *through improved operating and market efficiencies, consumer involvement*
- **Improved reliability** *leading to reduction in consumer losses (~$135B)*
- **Reduced losses and emissions** *through integration of renewables*
- **Increased grid robustness** *improving grid security*
- **New jobs and economic growth**
- **Opportunity to revolutionize the transportation sector** *through integration of electric vehicles as generation and storage devices*

Societal benefits must be included in the value proposition

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Some Challenges

Culture Change

A significant change management effort is needed:

- Why do we need to change?
- What is the vision?
- What is the value proposition?
- A new workforce with Smart Grid skills is needed
- Consumer education, alignment, and motivation is critical
- Metrics needed for accountability and to monitor progress
- Economies of intelligence – need active leadership

Our challenge is to align under a common long term vision and make our short term investment decisions consistent with the “end in mind”.

Technical Challenges

- Interoperability and scalability
- Large number of consumers actively involved
- Decentralized operations with 2-way power flow
- Getting the communications right
- “Future proofing” the technologies
- Cyber Security
- Fully integrated
- Conversion of data to information to action
- Market driven

Regulatory

- ***Time based rates -*** incentives for consumers to become actively involved
- ***Favorable depreciation rules –*** recovery of book value for assets that are retired early for "smart grid" reasons
- ***Policy changes that provide incentives and remove disincentives to utilities –*** investment in a Smart Grid should make business sense
- ***Clear cost recovery policies -*** uncertain cost recovery increases investment risk
- ***Societal benefits –*** quantified and included in business cases
- ***New regulatory models***

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Discussion Questions

What lessons have we learned from past complex system engineering projects that are most applicable to Smart Grid design?

- **U.S. Nuclear example**
  - Federal adoption of consensus standards
  - Lessons learned – best practices
  - Metrics
- **Credit Cards – broad transactional landscape**
- **Telecommunications and internet – compare and contrast**
- **Denmark Cell Structure**
  - Integration of renewables
  - Distributed, multi-technology solutions
  - Long-term vs. short-term vision

Which design factors are most important in terms of system stability and the flexibility to adapt to new inputs over time?

- **Ubiquitous (secure) communications infrastructure**
- **Interoperability of devices**
- **“Windows update” capability**
- **Transform the consumer – energy company link**
  - Initial education
  - Awareness like mobile phone transformation
  - Instant knowledge
  - Green consumer in control
- **Two-way power flow at distribution voltages**
- **Storage for arbitrage**

Which adoption standards are most critical in ensuring that smart grid systems are able to accept updated and new technologies and standards as they evolve?

- **Interoperability**
  - Energy “USB”
  - Cyber security embedded
- **New regulatory model**
  - Remove disincentives and add incentives to advance technology through deployment
  - Consistency among states
  - Disincentive to build big things until we have our asset utilization correct
  - “Least cost” and “used and useful”
  - “Appropriate” price signal

Would the implementation of individual elements prior to the creation of a unifying system design and process risk the long term stability of the smart grid?

Potentially:

- PHEV's without a price signal could result in making peak demand worse
- Early deployments of AMI without interoperability and cyber security standards in place could create financial risk to retrofit and increase the vulnerability of the grid
- Deployment of a communications platform without considering the full range of Smart Grid requirements could result in future rework and additional costs
- Widespread deployment of interconnected DG and storage without an advanced distribution management system to effectively operate them could challenge the reliability and safety of the grid

What type of governance structures and associated formal processes are needed to prioritize and oversee the highest value tasks?

- **Objective metrics structure open to the public**
  - National grid metrics
  - State grid metrics
  - Energy company (utilities, IPP, aggregators) metrics
- **Appropriate price signals that reflect real market conditions**
- **Smart Grid Certification Program like the EnergyStar program**

How can these structures and processes be best coordinated?

- **Metrics**
  - Legislation and supporting Federal grant program to states for establishing objective metrics and reporting progress to the public
- **Price Signals**
  - Collaboration among state and federal agencies to share lessons learned from past experiments – is there a “template” that can be adopted?
- **Smart Grid Certification**
  - Provides regulatory assurance to energy companies and vendors
  - Provides a clear technology picture for the investment community

For additional information, contact

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A Vision for the Smart Grid

Plugging America into the Future of Power

A Vision for the Smart Grid

What is the Smart Grid?

Introduction

Many people are asking, "What is the Smart Grid?" Many more are trying to define it with short "sound bite" descriptions. These short statements cannot adequately convey the level of detail needed to provide a clear understanding. The Smart Grid isn't a "thing" but rather a "vision" and to be complete, that vision must be expressed from various perspectives – its values, its characteristics, and the milestones for achieving it.

Smart Grid Values

The transformation to the Smart Grid will require new investment and commitment by its many stakeholders. These stakeholders expect significant value in return. Understanding how this value will be created is an important step in defining the vision. Expectations for the Smart Grid are great and will be realized through advances in each of the six value areas described below:

It must be more reliable. A reliable grid provides power, when and where its users need it and of the quality they value.

It must be more secure. A secure grid withstands physical and cyber attacks without suffering massive blackouts or exorbitant recovery costs. It is also less vulnerable to natural disasters and recovers quickly.

It must be more economic. An economic grid operates under the basic laws of supply and demand, resulting in fair prices and adequate supplies.

It must be more efficient. An efficient grid employs strategies that lead to cost control, minimal transmission and distribution losses, efficient power production, and optimal asset utilization while providing consumers options for managing their energy usage.

It must be more environmentally friendly. An environmentally friendly grid reduces environmental impacts through improvements in efficiency and by enabling the integration of a larger percentage of intermittent resources than could otherwise be reliably supported.

It must be safer. A safe grid does no harm to the public or to grid workers and is sensitive to users who depend on it as a medical necessity.

Smart Grid Principal Characteristics

The Smart Grid can be considered a "transactive" agent. That is, it will enable financial, informational, as well as "electrical" transactions among consumers, grid assets, and other authorized users. Its functionality is defined by the following seven principal characteristics:

First, it will enable active participation by consumers. The smart grid will give consumers information, control, and options that enable them to engage in new "electricity markets." Grid operators will treat willing consumers as resources in the day-to-day operation of the grid. Well-informed consumers will modify consumption based on the balancing of their demands and resources with the electric system's capability to meet those demands.

Second, it will accommodate all generation and storage options. It will seamlessly integrate all types and sizes of electrical generation and storage systems using simplified interconnection processes and universal interoperability standards to support a "plug-and-play" level of convenience. Large central power plants including environmentally friendly sources, such as wind and solar farms and advanced nuclear plants, will continue to play a major role even as large numbers of smaller distributed resources, including Plug-in Electric Vehicles, are deployed.

Third, it will enable new products, services, and markets. The Smart Grid will link buyers and sellers together – from the consumer to the Regional Transmission Organization. It will support the creation of new electricity markets from the home energy management system at the consumer's premise to technologies that allow consumers and third parties to bid their energy resources into the electricity market. The Smart Grid will support consistent market operation across regions.

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