Future History of Smart Grids: Communications Network Impacts

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October 6, 2010

Three Ideas About Smart Grid Networks

- Two major forces are changing communications networks for electric utilities
- Implications for communications network design
- True value of the smart grid communications network

Two Major Forces

Macro Drivers

- Step back from the specifics of AMI, DR, PEV's etc
- Look at how the grid must operate in the full scale Smart Grid environment

Macro Issues

  - Business model evolution
  - Grid management

Utility Business Model Evolution

Energy Delivery

Energy Delivery

+

Energy Information Management

Utility Business Model Evolution

Two Way Flow

N Way Flow

Image courtesy Eurogrids

Utility Business Model Example

- Potential model for wires companies
- Provide the market for small energy transactions
- Provide the transport mechanisms for energy transaction fulfillment

Advanced Grid Management Issues

- Grid mostly stabilized by inherent rotational inertia
- Some assistance via ancillary services
- Dispatchable generation

- Reduced rotational inertia; more instability
- Distributed Energy Resources/VER
- Stochastic generation

Advanced Grid Management Issues

- Electronic stabilization
- Wide area measurement; grid state observability; deep situational awareness
- Cross tier and vertically integrated control
- Adaptive protection, granular regulation (Volt VAr Regulation)
- Control system federation, hierarchical disaggregation

Advanced Grid Management Issues

“Fly-by-Wire”
Air Craft

“Fly-by-Wire”
Power Grids

- Need for high performance
- Must be agile for combat
- Unstable by design
- Electronically stabilized

- Need to integrate new capabilities
- Must be agile for reliability
- Unstable by evolution
- Electronically stabilized

Communication Networks Implications

- N-way flow of information -> IP
- Number of devices involved -> IPv6
- Security, QoS
- Low latency
  - Teleprotection: < 4 msec
  - System control: < 1 cycle (< 16 msec in North America)
  - FAN level: (DA) < 2 cycles (32 msec in North America)
  - Intra-substation: < 1 msec
  - WAMS: < 50 msec and decreasing over time
- Meter networks and MDMS are not adequate for distribution automation in the future

Communication Networks Implications

- Decentralization of measurement and control
- Network design driven by control and observability strategies
- Distributed data management and analytics in the network
- Virtualization of services into the communication network
- Distributed network/grid device management
- Embedding grid intelligence

Embedding Grid Intelligence in the Network

The network becomes *the* smart grid innovation platform

Make the power grid network-aware

- Enable peer-to-peer messaging for any grid application
- Give the grid views of network operations
- Rely on network for cyber security
- Rely on network for low level analytics
- Use network for data collection and aggregation
- Rely on the network for grid state distribution

Make the network power grid-aware

- Collect and aggregate grid data in the network
- Virtualize services and legacy devices
- Federate/disaggregate controls
- Support distributed intelligence
- Provide behavioral security; grid security, not just network security
- Manage grid devices as well as communication networks
- Implement core smart grid functions

What is the True Value of the Network?

“The value of information is precisely that of the decisions derived from it.”

John F. Hauer, PNNL, William A. Mittelstadt, BPA, Ken E. Martin, BPA
Jim W. Burns, BPA, and Harry Lee, BC Hydro
“Integrated Dynamic Information for the Western power System: WAMS Analysis in 2005”, Power System Stability and Control, CRC Press, 2007

- Value Integral

$$\text{value} = \int \sum (\text{decision values})\ dt$$

- Metcalfe/Zipf’s Law: Bob Briscoe, Andrew Odlyzko, and Benjamin Tilly, IEEE Spectrum, July 2006, pp 35-38

$$\text{network value}(n) \approx n \log(n)$$

Two Examples

- Example: AMI
  - Small value decisions for consumers based on smart meter data
  - Very large number of decisions over customer base (large n)
- Example: WAMS (PMU networks)
  - High value decisions (avoiding wide area blackout)
  - Small number of endpoints (small n)

True Value of the Smart Grid Communications Network is Based on the Value of the Grid Information It Manages

INNOVATION

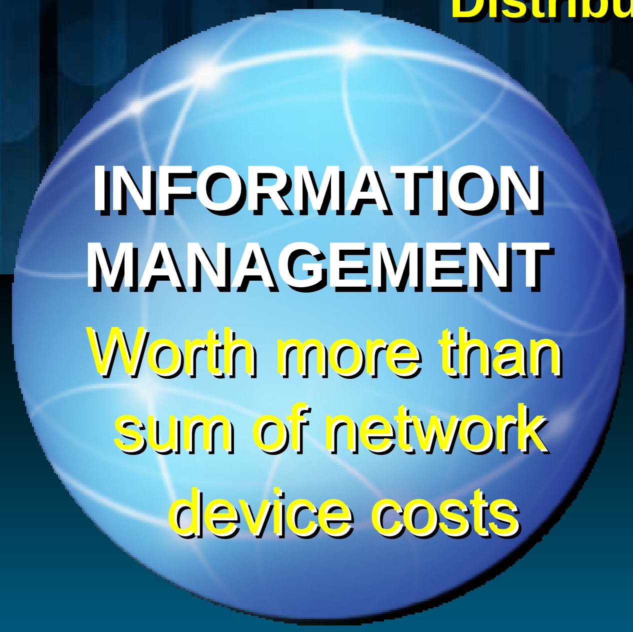
Smart Grid Core Functions

Standards

Protocols

Virtualization

Services



Distributed Intelligence

Grid Awareness

Security

Network Management

OPERATIONAL EXCELLENCE

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