Future History of Smart Grids: Communications Network Impacts

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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

OLD

+ Energy Information Management

NEW

Energy Delivery
Utility Business Model Evolution

OLD

Two Way Flow
N Way Flow
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

OLD

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

NEW

- 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

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

“Fly-by-Wire”
Power Grids

- 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


- **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

Worth more than sum of network device costs