Experiences from deploying real smart grid projects

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Storage, Compensation, Self Healing… in the Grid

Communication Media: BPL, Wi-Max, Satellite, Fiber, DSL, Wi-Fi, RF Mesh, etc.

Smart Grid Infrastructure: Software/database, network communication and monitoring, and control architecture
Successful Policy … Driving Growth

US Annual Wind Installed Additions

- Partial PTC Year
- Full PTC Year
- Forecast with PTC extension

Renewable Portfolio Standards

- 36 States & DC

Aggressive Global Targets

- US … 20% Wind ‘30
- EU … 20% Renewable Energy ‘20
- China … 30 GW Wind ‘20
- India … 12 GW Wind ‘12
Reactive Power Requirements

• Capability of synchronous generators forms basis for wind interconnection requirements

• FERC Order 661A is a USA grid code for maintaining power flow limits, voltage limits, and voltage control:
  – Low voltage ride-through (LVRT)
    • Generator stays on line during a 3 phase fault with normal fault clearing (~4 to 9 cycles) and subsequent post fault voltage recovery to prefault voltage unless clearing the fault disconnects the generator
  – Power factor +/- .95 with dynamic voltage support
Reactive Power Compensation

• Collector substation-based systems
  – Mechanically-switched capacitors and reactor banks
  – Static Var Compensators
  – Hybrid compensators

• Inverter-based dynamic component
  – 1.25 MVAR modules
  – 264% of continuous rating for 2 to 4 seconds
    • LVRT support
    • Dynamic range requirement
  – For transient / dynamic events
  – Use with mechanically switched capacitors and reactors
Inverter-based Dynamic Compensators

DSTATCOM: Typical configuration

Supporting over 2.5 GW of wind generation

Meeting Interconnect Requirements for 12 different Grid Codes/ System Operators
Reactive Compensation System Installations

- Argonne Mesa, New Mexico
  - 90 MW
  - Mitsubishi MWT1000 WTGs
  - ±12 MVAR DSTATCOM and 91 MVAR switched capacitors
  - Controlling power factor at POI 30 miles away
**Reactive Compensation System Installations**

- **High Lonesome, New Mexico**
  - 100 MW
  - 40x Clipper 2.5 MW WTGs
  - ±6.25 MVAR DSTATCOM and 3x 7.43 MVAR switched capacitors (2 as damped tuned harmonic filters)
  - Controlling voltage on high side of main wind farm transformer, which is 13.4 miles from the POI
Reactive compensation in UK

±6.25/16.5 MVAR on 48 MW Wind Plant application controlling 3 SSDs
  – Two switched total cap banks of 8 MVAR
  – One switched reactor bank of 7 MVAR
Energy Storage

- Energy Storage Benefits
  - Cost deferral of new substations
  - Improved service reliability
  - Less stress on aging infrastructure
  - Integration of renewable energy
  - Energy market value
  - Frequency regulation

- Several 1 – 4 MW NaS batteries installed in the US
  - Peak shaving for a station transformer
  - Dynamic islanding with distribution automation integration
  - More dispatchable wind generation
Charleston, WV: 1MW NaS Battery

- Chemical Substation, Charleston WV
- Store energy off-peak to Sodium-Sulfur battery
- Reduce substation peaks by injecting stored energy
- Technology demonstration project
- Objective—defer replacement of 20 MVA transformer

**Chemical Substation: Transformer Load**
Three Worst Days of Summer (7/19, 8/2, and 8/3/2006)

- Maximum Load: 20.365 MVA (with Battery)
- Maximum Load: 21.234 MVA (without Battery)
- Minimum Load: 11.537 MVA (without Battery)
- Minimum Load: 12.735 MVA (with Battery)

Charge: 1.2 MW, 7 hrs
Discharge: 1.0 MW-peak, 8.5 hrs

**SMS Reduced the Peak Load to match the Transformer Rating**
Bluffton, OH: 2 MW NaS Battery

- 2.5 MVA / 2.0 MW – Outdoor Installation
- Automated islanding, sectionalizing, and restoration
- Generator for heater backup power
Luverne, MN: 1MW NaS Battery

- 1.25 MVA / 1.0 MW – Outdoor Installation
- Wind farm smoothing
- Dispatched wind
- Peak shaving
- Energy arbitrage
Presidio, TX: 4MW NaS Battery

- 5.0 MVA / 4.0 MW – Indoor Installation
- Automated islanding, sectionalizing, and restoration
- Alternate Utility (CFE) source for heater backup power
Dynamic Islanding

• Load data known by automated distribution devices
• Dynamic islanding activated upon loss of power
• The maximum number of customers are restored
  serviced by the battery based upon:
    – Last load information
    – Energy in the battery
• The island can be minimized as the battery depletes
• Customer load served until battery is exhausted or
  power is restored
Community Energy Storage

- Develop distributed storage at the utilization voltage level
- 25 kW, single-phase, pad-mounted
- 1-hour run-time initially
- Local voltage regulation
- Peak shaving
- Load smoothing – buffer plug-in vehicles
- Aggregate control of pad-mounted units serving multiple residential or light commercial customers
Lessons

• Suppliers
  – Need to work with others
  – Consider backward / forward compatibility
  – Support interoperability standards
  – Stay abreast of security requirements, policies and technologies
  – Seek technologies from non-traditional sources

• Users
  – Think through the macro smart grid roadmap
  – Work with others for technology assessments
  – Gain experience with integrated deployments
  – Validate business case assumptions
  – Build regulatory confidence
IEEE Smart Grid

- Organize, coordinate, leverage and build upon the strength and experience of all IEEE entities

IEEE Transaction on Smart Grid
IEEE Transaction on Sustainable Energy
http://mc.manuscriptcentral.com/pes-ieee

Reprinted 2009 Smart Grid articles.

http://smartgrid.ieee.org/
Conclusions

• Smart grid is an enabler
  – Maintaining / enhancing reliability
  – Integrating new resource development
  – Facilitating customer participation

• Smart Grid requires a new look at operations, planning, markets, technology, standards and workforce adequacy

• Technologies are available – use them

• IEEE Smart Grid is the number one resource
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