I skate to where the puck is going to be, not where it has been.

Wayne Gretzky

NASPI Conference
October 13, 2011

Larry Bekkedahl
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Applications

• **Planning Applications**
  - Reliability starts with good planning – understanding the system and making the right investment decisions

• **Wide-Area Situational Awareness (WASA)**
  - Give power system dispatchers and tech staff greater visibility of electric power grid

• **Improvements of the existing EMS applications**

• **State estimation**

• **Stability Controls (WACS)**
  - Unlock transmission capacity, provide “defense in depth” against blackouts
Notice & Wonder
“Those who forget the past are condemned to repeat it”
Power Plant Model Validation

- What a bad model looks like (800 MW steam-turbine unit)

Voltage and frequency are inputs
Active and reactive power are “measures of success”

Blue line = actual recording
Red line = model
Modeling Governor Response Validation

- PMU data was very instrumental in identifying which power plants are responsive, under load control or base-loaded.
- Several model improvements were made – gas turbine models, Kaplan hydro-turbine models.


**BEFORE**
Four Corners Plant Outage on December 25, 1999

**AFTER**
Four Corners Plant Outage on December 25, 1999

Blue = actual, Red = model
This is actual data, not simulations
Same plant
All lines in service
Wind ramping up event
Wind power plants are in **power factor** control mode
PV-Curve for same event
Voltage Control

This is actual data, not simulations
Same plant a couple of weeks later
All lines in service
Wind ramping up event
Two wind power plants are under voltage control
Had we had Model-Based Stability Analysis

Limits are set using model-based stability analysis

Power - Voltage Curve

Limit

Actual measurements

Model-calculated PV-Curve

Voltage (kV)

Power (MW)
Variability: how to lower the uncertainy

- Operations & geography mitigate variability & cost
  - Smaller scheduling and dispatch intervals
  - Optimizing existing balancing resources
  - Improving wind forecasting
  - Load shaping
  - Geo-diversity and transmission

- As Wind grows, demand for flexibility increases
  - Not flexible: coal & nuclear
  - Environmental and political pressure

- New generation resources a better fit, more flexible
  - Solar: offsetting diurnal pattern
  - Steam turbine gas plants (CCGT) = flexibility for load changes
  - Gas turbine plants (SCGT) = most flexibility for regulating/peaks

- Variability decreasing as wind integration evolves
  - Need to accelerate the evolution

New York ISO

Could Smart Grid help?

Wind
Power Plant architecture & controls

- Voltage, Frequency & Reactive Power control
- Dynamic & integrated plant response capability
Utility Drivers

• 1990’s – Deregulation
• 2000’s – Incentive based maintenance
• 2003/current – Compliance

• How much R&D was included in these industry trends?
• Have any of these industry trends created innovation?
WHEN IS THE LAST TIME THIS DEVICE WAS UPGRADED? IT REALLY NEEDS TO BE MORE USER FRIENDLY. WHO'S IN CHARGE OF INNOVATION UP HERE? IS THIS AVAILABLE IN OTHER COLORS?

STEVE JOBS 1955-2011
“Being the richest man in the cemetery doesn’t matter to me. Going to bed at night saying, I’ve done something wonderful. That’s what matters.”

“It’s the intersection of technology and liberal arts that makes our hearts sing.” What makes your heart sing?

Steve Jobs 1955-2011