Overview

- Extension of work with Davis Power Consultants and the California Energy Commission
- Prior Analysis
  - Examine magnitude and frequency of contingency overloads as a simple measure of system reliability
  - Compare base cases to those with different penetrations of distributed renewable resources
Overview

• Intermittency Analysis
  – Integrate the contingency overloads over time to study the impact of wind intermittency on system reliability
  – Use Simulator’s Time Step Simulation (TSS) to model time-varying wind production
  – TSS enables collection and analysis of a large amount of data with a modest investment in setup time

Intermittency Challenges

• Wind plants are generally developed… where the wind blows!
• If EHV transmission is in the vicinity, it is usually by coincidence
• Wind production is unpredictable
• Transmission network must support a multitude of wind production patterns across varying:
  – load conditions
  – production patterns of thermal and hydro resources
Wind Turbine String

Typical Wind “Transmission”
Intermittency Challenges

• Wind production is usually highest during off-peak hours
  – Fast load following resources are off-line
  – Moderated in California, where even simple cycle units may serve as base load resources

• Voltage regulation
  – Var-producing generators are often distant
  – LTCs and caps must switch frequently

Summary of Prior Analysis

• Identify links between electricity needs in the future and available renewable resources.

• Optimize development and deployment of renewable resources based on their benefits to:
  – Electricity system
  – Environment
  – Local economies

• Develop a research tool that integrates spatial resource characteristics and planning analysis.
Objectives

- Investigate the extent to which renewable distributed electricity generation can help address transmission constraints
- Determine performance characteristics for generation, transmission and renewable technology
- Identify locations within system where sufficient renewable generation can effectively address transmission problems

Objectives

- Determine the impact of large-scale distributed projects on grid security.
- We need to:
  - Identify weak transmission elements and define metrics that assess system security.
  - Find locations where new generation would enhance the security of the grid.
  - Combine maps of beneficial locations with maps of energy resources.
Normal Operation Example

System does not have normal operation thermal violations

Contingency Example

Then this line gets overloaded (is a weak element)
This is a serious problem for the system

Suppose there is a fault and this line is disconnected

Planning Solutions:
New line to bus 3
OR
New generation at bus 3
Contingency Analysis

- Security is determined by the ability of the system to withstand equipment failure.
- Define weak elements as those that become overloaded during contingency conditions (congestion).
- Perform N-1 contingency analysis simulation.
- Apply ranking to help prioritize transmission planning: Aggregate MW Contingency Overload (AMWCO)

Results Organized by Lines, then Contingencies

Sum each value-100 to find the Aggregate Percentage Contingency Overload (APCO)
Weak Element Visualization

June 14-15, 2006
2006 Power World Client Conference: Wind Power Intermittency

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Intermittency Analysis: Time-Step Simulation

- 2100 MW wind capacity across five regions
- Historic hourly wind production capacity factors are known for each region
- Apply known capacity factors to existing and planned capacity to create simulation inputs
- Match production patterns to characteristic power flow cases
  - Apply summer peak pattern to summer peak case, winter peak pattern to winter peak case, etc.
  - Hold load constant within each case
- Follow the wind production with natural gas resources

Intermittency Analysis: Time-Step Simulation

- Run contingency analysis at each step
- Store results for each line and transformer at each hourly time step
  - AMWCO for contingencies
  - % of limit used for each base case (non-contingent operation)
- Extend AMWCO metric over time: Aggregate MWh Contingency Overload
- Examine variability of results
- Identify potentially vulnerable transmission paths
Wind Generation in California

Solano County: 230 MW
Altamont Pass: 600 MW
San Gorgonio Pass: 500 MW
Pacheco Pass: 13 MW
Tehachapi: 800 MW (additional 4000 MW planned)

Note: capacities shown are from 2005 power flow case used in simulation.

Input Data:
Hourly Gen MW for each Wind Generator

336 time points representing summer peak hours

Values based on historical regional production capacity factor, applied to simulated regional capacity.
**Input Data:**

Follow Wind with Natural Gas

AGC set to YES for Natural Gas units, NO for others

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**Contingency Analysis**

- Set Each Hourly Field (Run CTGs) to YES
- Time Saving Measures
  - Filter the N-1 contingency list
    - Include only contingencies that cause overloads in the base case (before applying any hourly scenario)
  - Reduced number from 5000+ to 195
  - Use linearized lossless DC calculation
Results Grid

Contingency analysis shown in process

System AMWCO Duration

A few hours experience unusually high level of overloads; rest of curve is fairly flat
Hourly Line Loadings

These three lines show very different loading patterns:

- Red: high average loading, low variability
- Green: low avg loading, high variability
- Blue: low avg loading, low variability overall, but heavily impacted during certain conditions

Line Loading Duration Curve

Shown are the same three lines from prior slide
Aggregate MWh Contingency Overload (AMWhCO)

Red indicates lines most severely overloaded over time.

Overload Variability

- Shows AMWhCO relative to a reference (median hour)
- Many overloaded lines experience consistent levels at nearly every hour – wind intermittency is not a big factor
- Red indicates lines most adversely affected by intermittency
- Green indicates lines favorably affected by intermittency
Time-Step Simulation

- TIP: It is helpful to use an external database for managing TSS inputs and results
  - Perform calculations to determine inputs
  - Paste inputs into TSS grid
  - Query and filter based on statistical criteria
  - Create time-integrated graphs
  - Paste time-integrated results into Simulator’s custom float fields for contouring
Conclusions

- As integration of wind power on the grid increases, intermittency issues will become more significant
- Simulator’s TSS offers a robust and efficient environment for studying time-scale phenomenon such as wind intermittency
  - Easy to set up, especially for a modest number of input variables
  - Many results can be stored and accessed within the Simulator TSB file without having to catalog multiple power flow cases

Conclusions

- An external database may be very helpful for preparing inputs, screening results, and integrating results over time
- Some plots are available in Simulator for viewing inputs and results
- Complex plots may be readily produced from a good external database