Value of Storage with Increased Renewable Penetration

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Problem Statement

- Renewable energy portfolio standards
  - High penetration of intermittent and variable renewable generation on the grid
  - Utilities constrained by NERC Control Performance Standards
  - Requires additional resources to match generation with load
- Mitigation of impacts with energy storage
  - At what level of renewable penetration does energy storage become an attractive value proposition?

Conceptual Approach

- Develop a simplified dispatch model that simulates load distribution among a given set of generators to evaluate value of storage with increasing renewable generation
  - Identify renewable penetration thresholds where storage becomes economically viable
    - ACE Fines + Generation Costs > Storage Costs
  - Quantification of generation costs
    - Fuel costs, start-up and shut-down costs, ramping costs
    - Area Control Error (ACE) and associated NERC fines
  - Quantification of storage costs
    - Flywheels and compressed air energy storage (CAES)
    - Other types of storage to be considered (generic storage implementation)

Dispatch Model

- Model Details
  - System dynamics model in PowerSim Studio
    - Tracks power flow and accumulates energy
  - Spatially lumped
    - No transmission losses or transmission constraints are considered
  - Simulation Settings:
    - Time Step = 1 minute
    - Duration = up to 1 month
  - Approximates the New Mexico Balance Area
    - Generator specifications
    - Load and wind data

Dispatch Model

- Dispatchable Generator Control
  - Priority dispatch of generators based on order of maintenance and operation costs
    - Coal $/MW < CC $/MW < GT $/MW
    - Nuclear always on
    - Exchanges occur in blocks and only during peak hours
  - Generation limits of individual generators are constrained by look-up tables
    - Keeps generators within operational limits
  - Generator response to load is limited by generator specific ramp rates

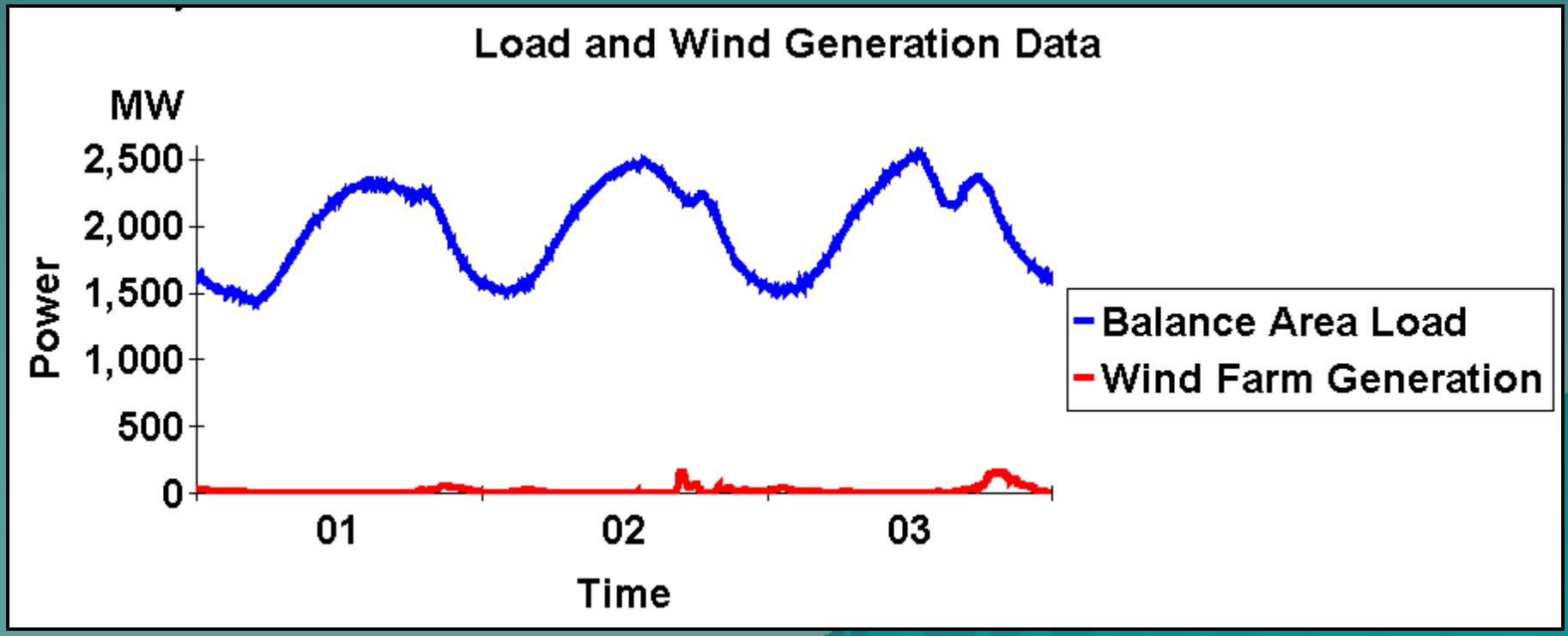
Dispatch Model

- Generator Data

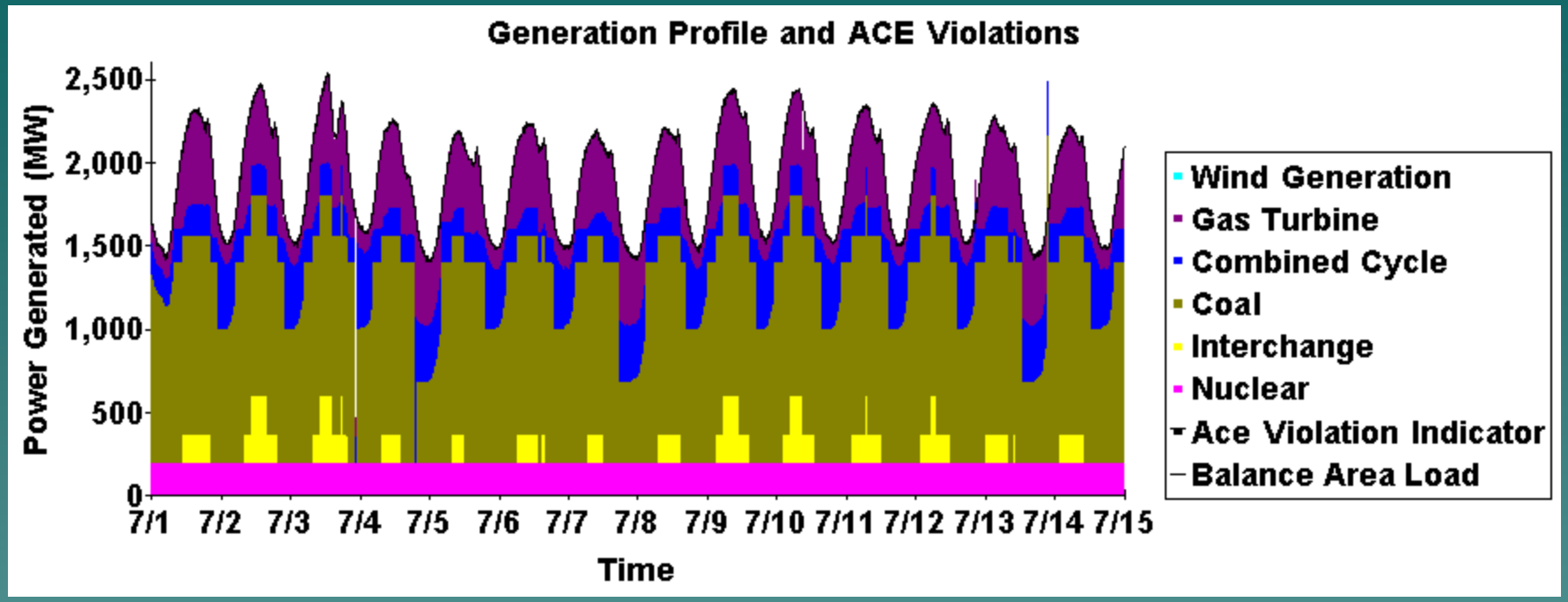
Generator Type	Number of Units	Per Unit Min-Max Capacity (MW)	Load Follow and Regulation (% of Capacity)	Maximum Ramp Rates (MW/min)
Nuclear	1	200	0	0
Coal	3	320-400	20	10
CC Gas	1	140-200	30	20
Gas Turbine	6	60-100	40	30
Interchange*	NA	NA	NA	NA

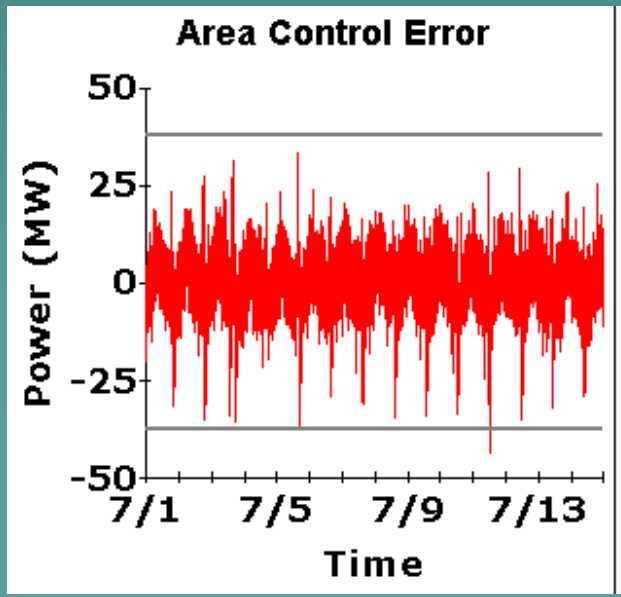
Load and Wind Data

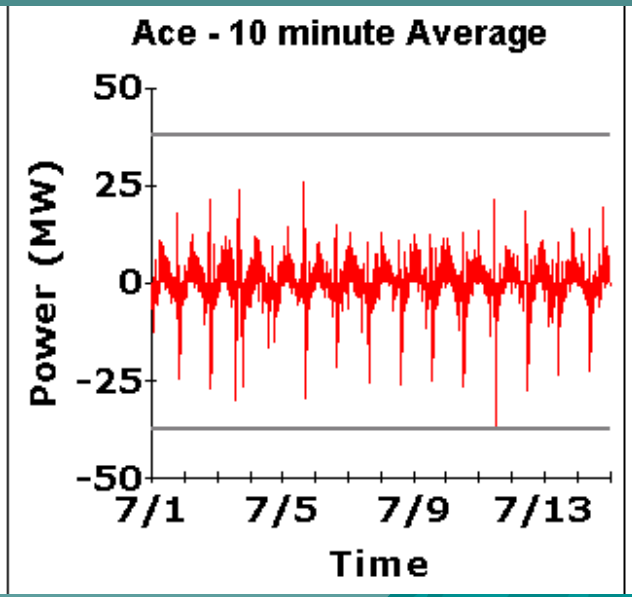
Data Type	Source	Duration	Time Step	Statistics
Load	New Mexico Balance Area	July 1 to July 31 2007	1 Minute	Range = 1403-2541 MW Average = 1929 MW SD = 301 MW
Wind	New Mexico Wind Farm	July 1 to July 31 2007	10 Minute	Range = 0 – 189 MW Average = 28 MW SD = 28 MW

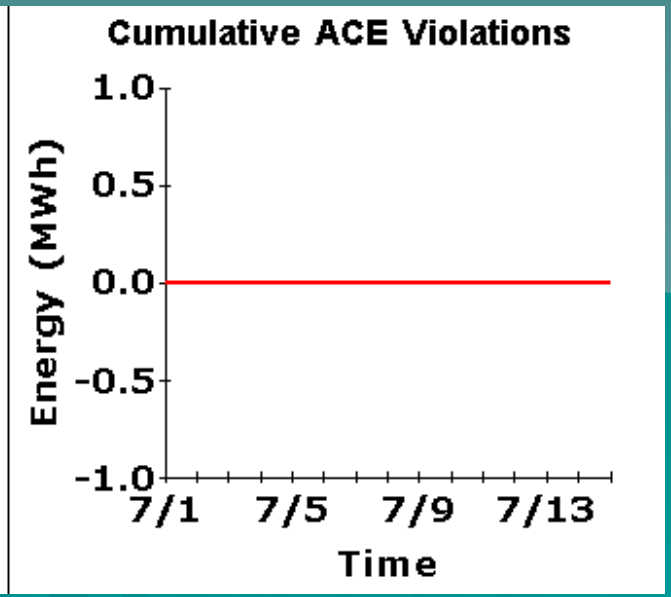


Dispatch profile– no wind generation

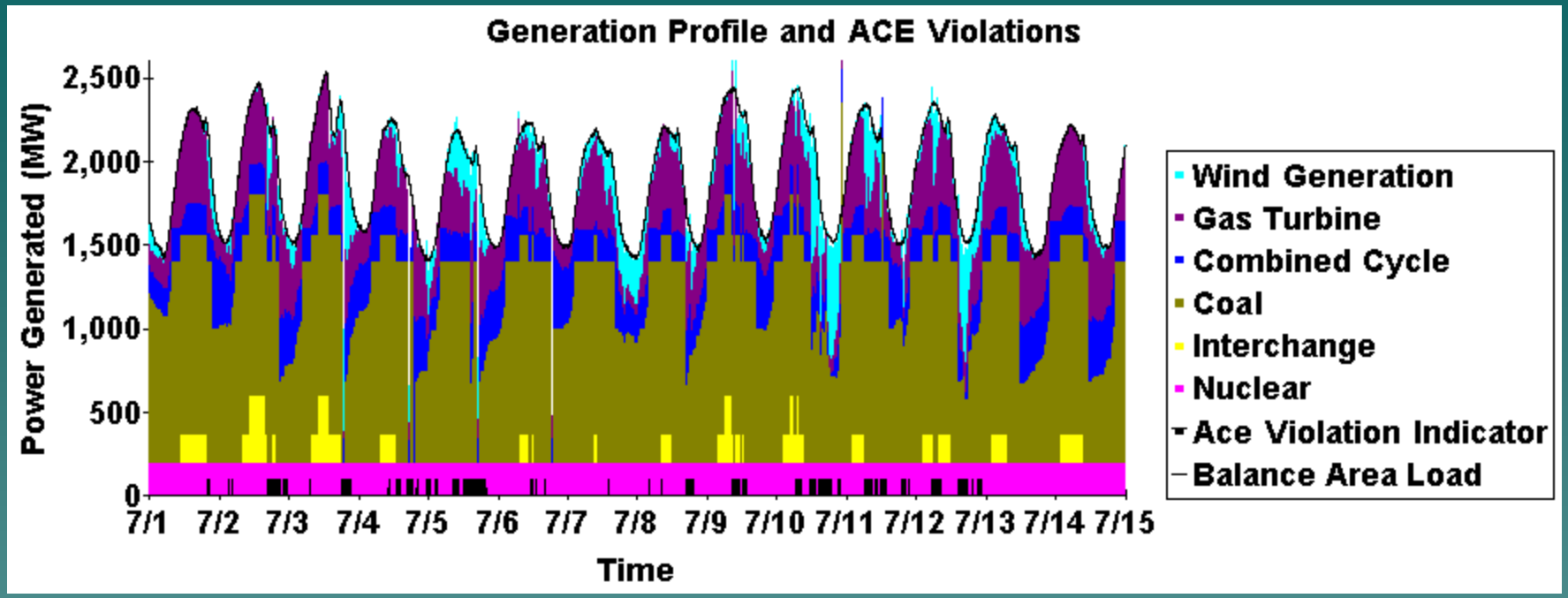


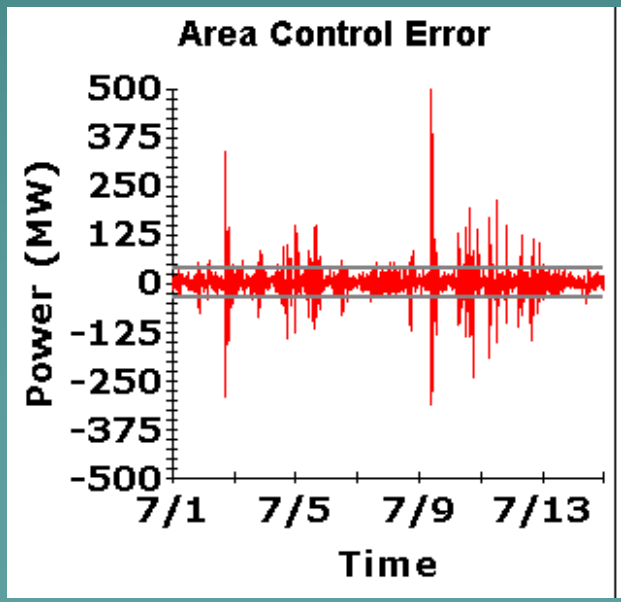


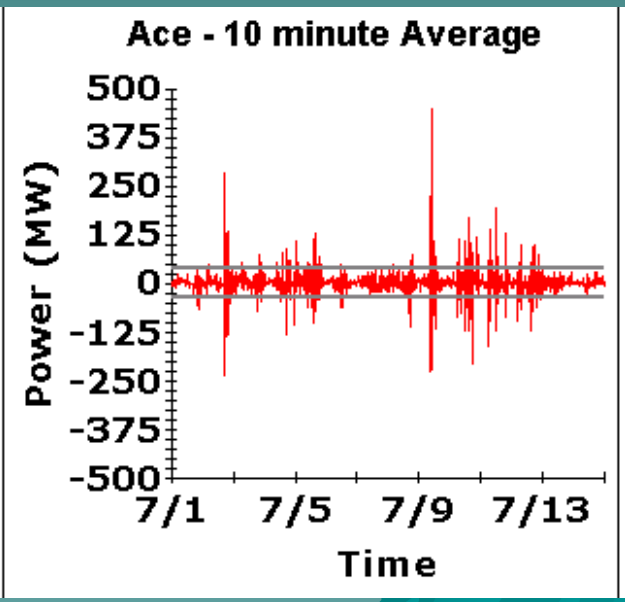


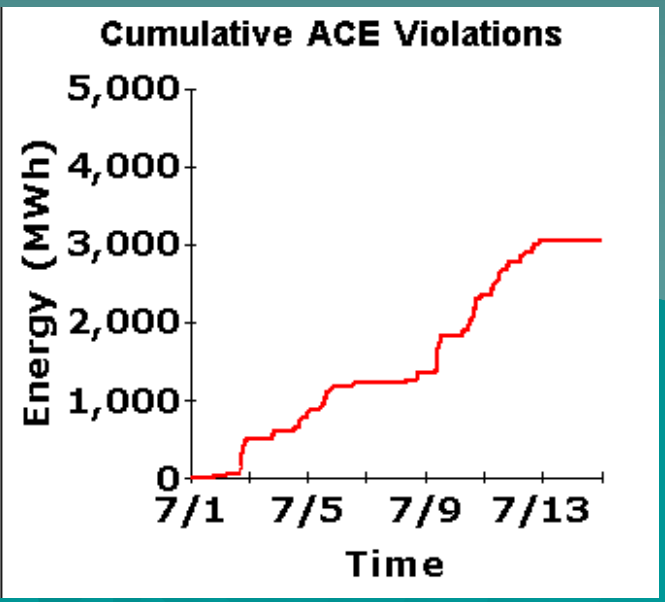


Dispatch profile – wind at 5% of total generation

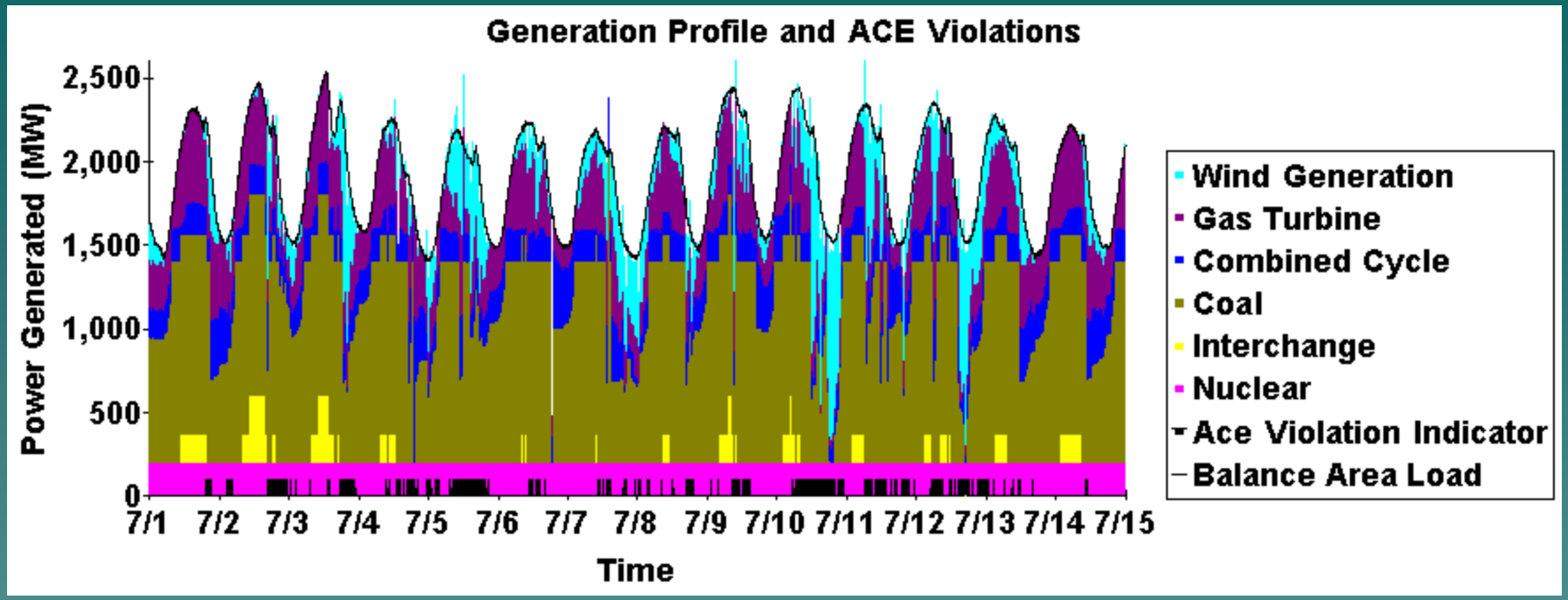


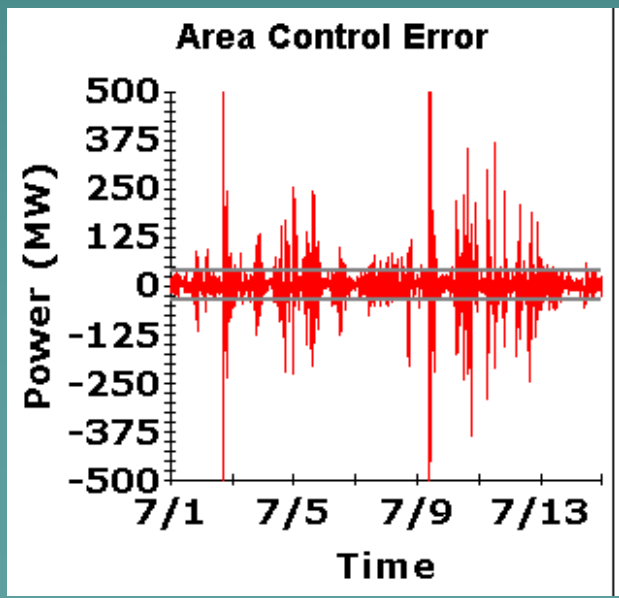


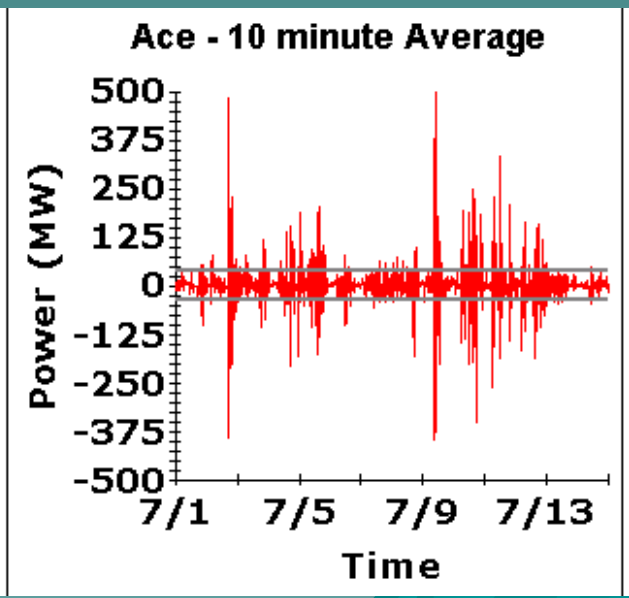


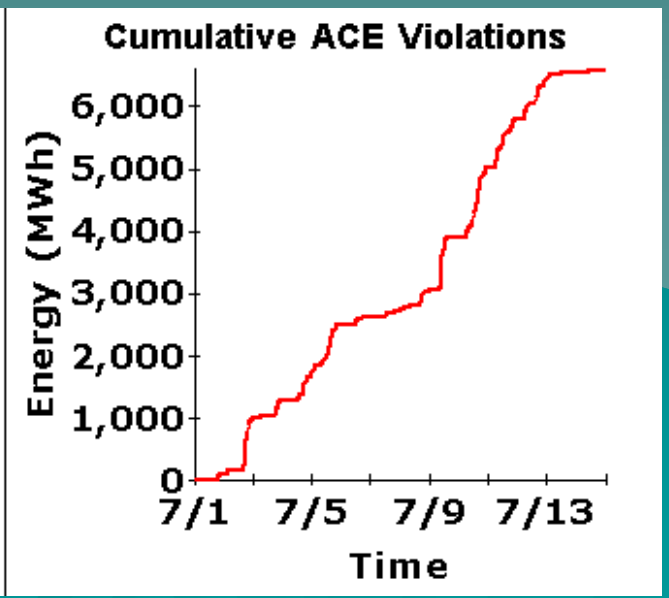


Dispatch profile – wind at 10% of total generation

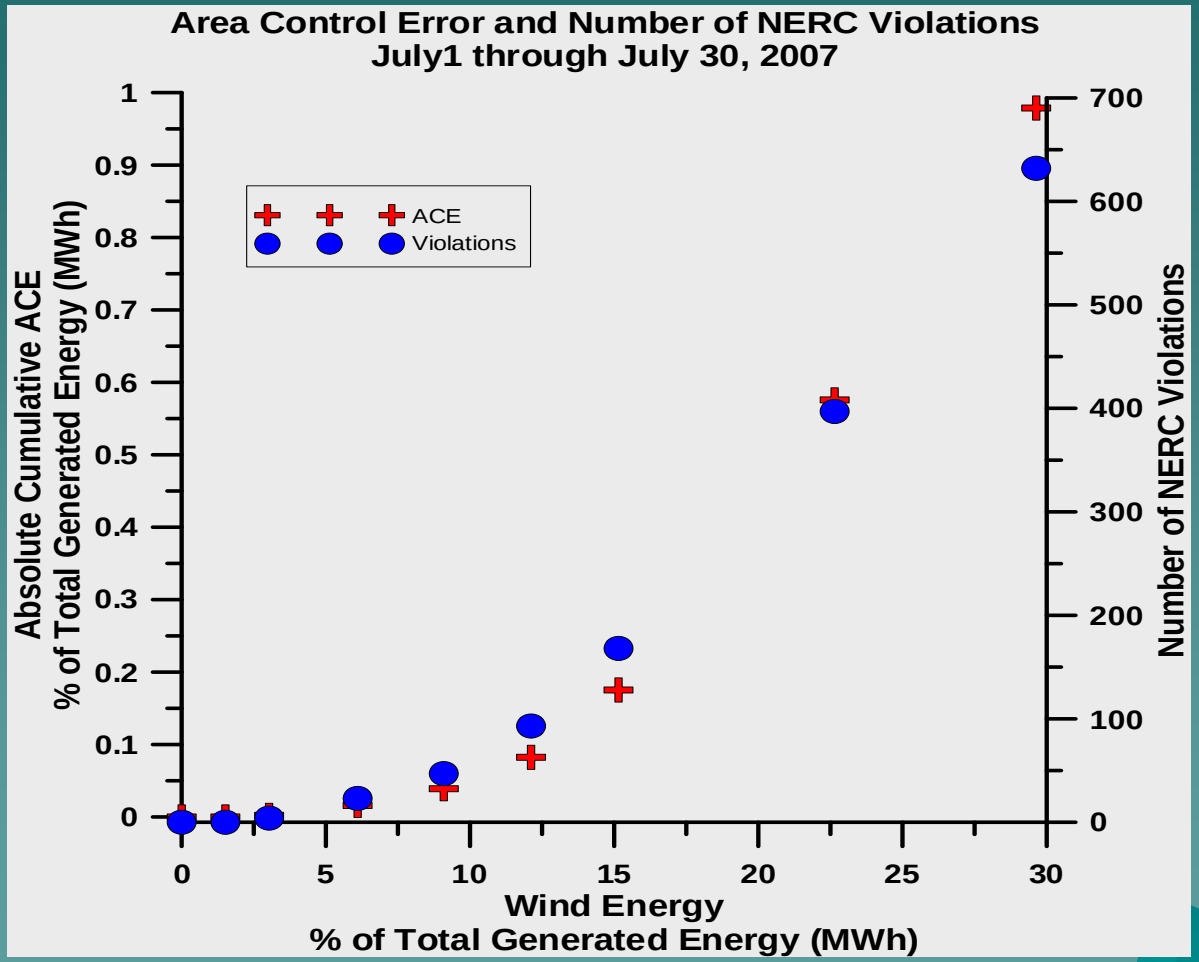








Cumulative ACE & NERC Violations as Wind Penetration Increases



Summary and Conclusions

- Approach
  - Use a simplified, yet robust dispatch model that
    - Incorporates New Mexico Balance Area load and wind generation data
    - Distributes the load among a suite of generators
    - Quantifies increased generation costs with increased penetration of intermittent and variable renewable generation
      - Fuel, startup, shut down, ramping, standby, etc)
    - Tracks and quantifies NERC penalties and violations
    - Quantifies storage costs

Summary and Conclusions

- Status
  - Dispatch model has been constructed
    - Accurately distributes a load among a suite of generators
    - Quantifies duty cycle metrics for each of the generators
      - Cumulative energy production, ramping and non ramping duration, spinning reserves, number of start-ups, and shut down durations, etc.
    - Quantifies energy exchanges
      - Cumulative exchanges, duration, and number of exchanges
    - Tracks ACE violations

Next Steps

- Add day ahead unit commitment and hour ahead automatic generating control commitment
- Generation data related tasks
  - Investigate ways to upscale wind generation data
  - Add April load and wind generation data
  - Add PV data
- Incorporate a NERC violation sensitive standby and spinning reserve routine
  - Dispatch becomes more conservative as number of violations in a month approaches critical level

Next Steps

- Add storage component
  - User defined storage performance characteristics:
    - Capacity, efficiency, self decay, max charge and discharge rates, max ramp rates, other?
  - Include default values from CAES, flywheel, battery, and pumped hydro technologies
- Add economics
  - Generation and NERC Fines
  - Storage