Power System Operations Hands On Relay School March 18, 2016

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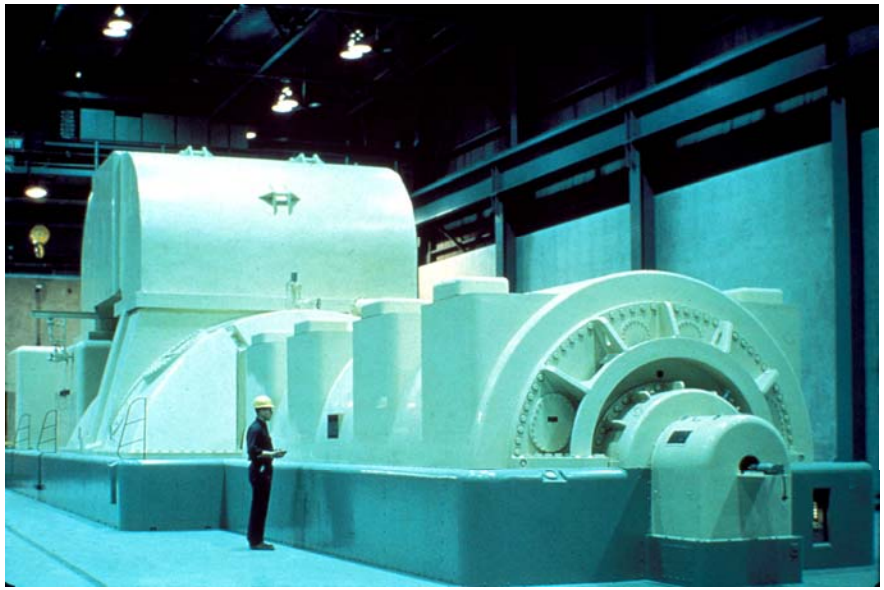
Avista Utilities

What are we trying to do?

- Convert some form of energy into electric energy
- Transmit the energy from the generator to the load
- Deliver to the load as needed
- For an AC system
  - Spin a magnet in a coil of wire
  - Connect the wire to the load
  - Turn something on

AC System is a Rotating Machine



- Large mass
- Lots of inertia
- Frequency response / speed governors

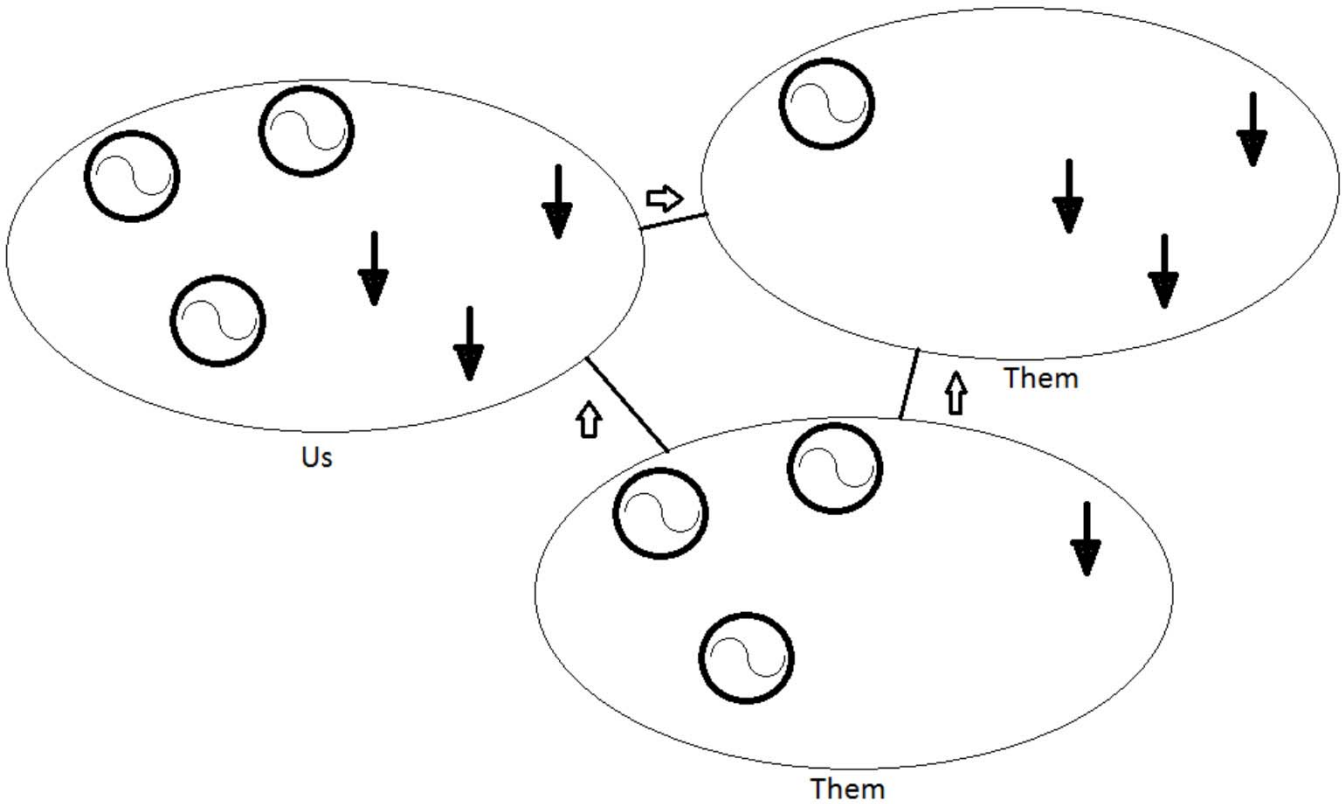
System is Changing

- DC Inverters
- Different operating characteristics
- Distributed Energy Resources
- Still learning

Traditional Utility Model

- Integrated operations
- One owner/operator for
  - Generators
  - Transmission System
  - Distribution Systems
- Control Area Operator
  - Control from generator to retail customer

Traditional Utility Model

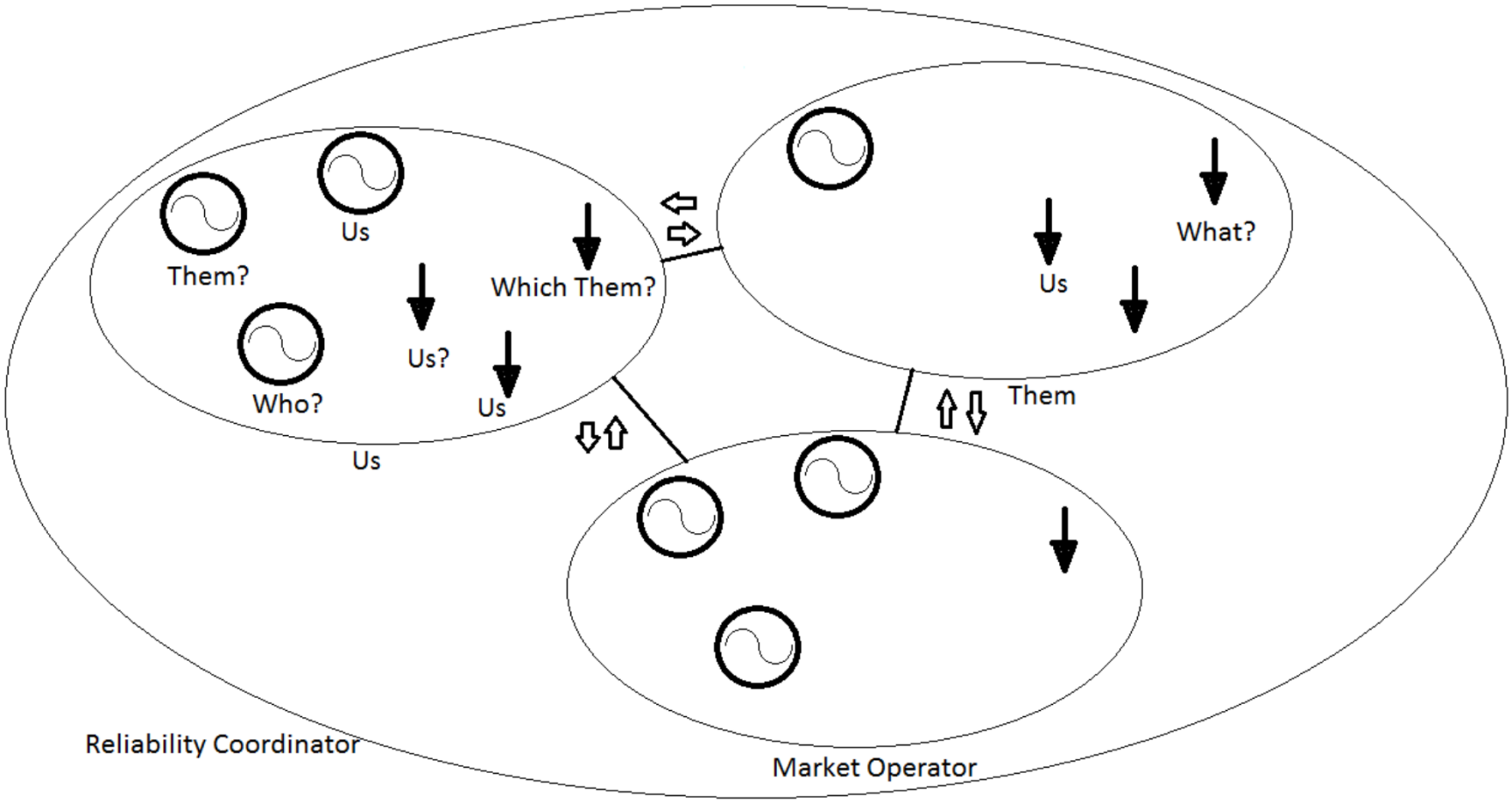


Control Areas

Today's World

- NERC Functional Model – 1999 - 2004
- No single owner operator
- Markets have formed
- Reliability Coordinator established
- Control Area has been broken up into functions
  - Balancing Authority – Load resource balance, frequency control, generation dispatch
  - Transmission Operator – Voltage control, transmission scheduling, transmission switching
  - Generator Operator – Plant operations
  - Market Operators – Mishmash of BA, TOP, GOP functions

Functional Model



Balancing Authority

- The responsible entity that
  - Integrates resource plans ahead of time
  - Maintains load, interchange, generation balance within a Balancing Authority Area
  - Supports Interconnection frequency in real time
- Balancing Authority Area
  - The collection of generation, transmission, and loads within the metered boundaries of the Balancing Authority
  - Does not need to be contiguous – Pseudo Ties
- Balancing Authority is analogous to Control Area without control of transmission facilities

BA Operations Pre-Schedule

- Load Forecast
- Generation Schedule
- Net Scheduled Interchange (NSI)
  - Export is positive
  - Import is negative
- Load Forecast = Generation Schedule – NSI
- Contingency Reserves – Generators trip
  - MSSC or 3/3 percent of load/generation
- Operating Reserves – Regulation, forecast error
- This is the PLAN

BA Operations Pre-Schedule

- Net Scheduled Interchange
  - Sum of Scheduled Transactions
- Each transaction is an Electronic Tag / E-tag
  - Source BA
  - Transmission Path
  - Sink BA
- Sum of E-tags (transactions) is NSI
- NSI is verified with counterparties before operating hour

BA Operations Real-Time

- Area Control Error (ACE) – real-time measure of balancing
- ACE = NAI – NSI - 10B(Fa-Fs) – ME + ATEC
  - NAI – Net Actual Interchange
  - NSI – Net Schedule Interchange
  - Frequency Bias MW/0.1Hz
  - ME – Meter Error
  - ATEC – Automatic Time Error Correction (WECC)
- ACE drives Automatic Generation Control (AGC)
  - Negative ACE, pulse units up
  - Positive ACE, pulse units down

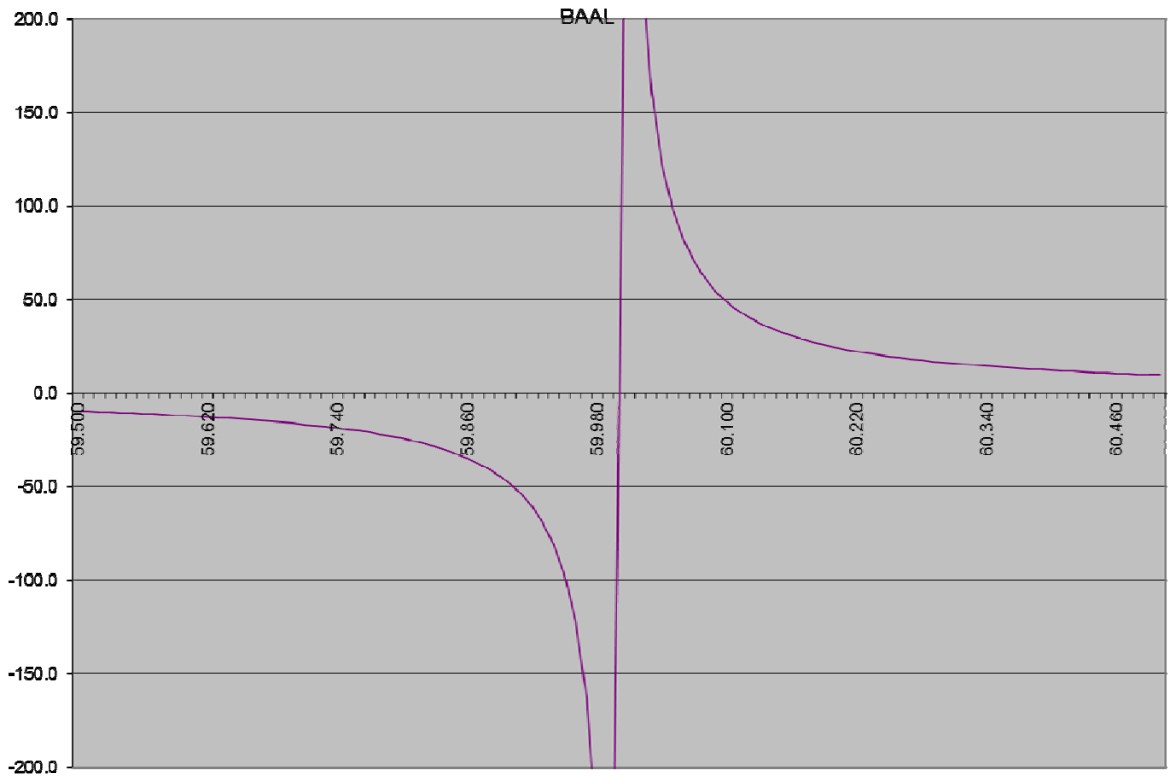
Control Performance Standard 1 – CPS1

ACE	Frequency	Good or Bad?
Positive	High	Bad
Positive	Low	Good
Negative	High	Good
Negative	Low	Bad

- CPS1 is one-month and twelve-month measure
- Are we following the PLAN?

BA ACE Limit - BAAL

- Real-time measure
- Replaces CPS2 limits

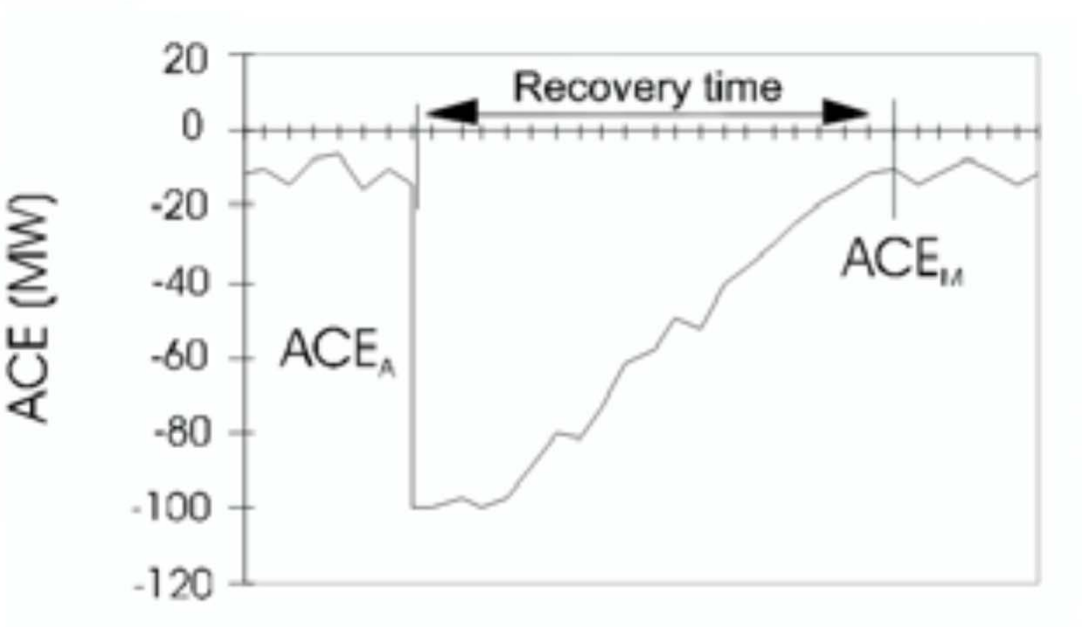


BA Operations Real-Time

- Contingencies – Loss of Generation
- NAI decreases, driving ACE negative
- BAL-002 Disturbance Control Standard (DCS)
- ACE must be returned to pre-contingency ACE (or zero if ACE was positive) within 15 minutes
- Contingency reserves are used to recover
- Firm load shedding is not appropriate for DCS recovery
  - Interruptible load can be used as operating reserve

BA Operations Real-Time

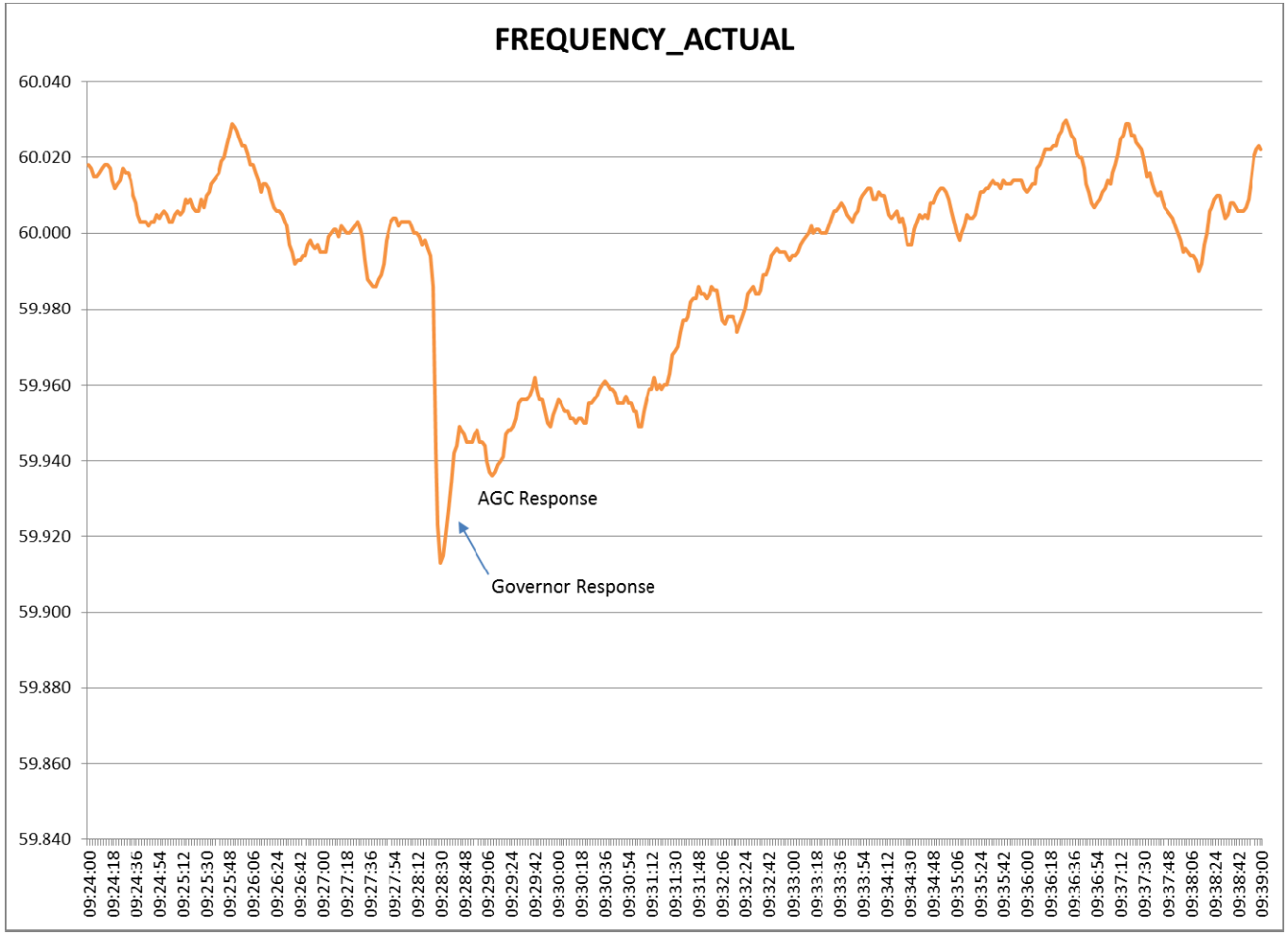
Generator Trip and ACE Recovery



BA Operations Real-Time

- Frequency Bias Term in ACE – B MW/0.1Hz
  - Responds to off nominal frequency
  - High frequency raises ACE
  - Low frequency lowers ACE
  - AGC is slow acting – minutes, not seconds
- Governor Response
  - Instantaneous – seconds
  - Arrests frequency decline
  - Stabilizes system until AGC begins acting

BA Operations Real-Time



BA Operations After-the-Fact

- Integrated values for the hour (Hour Ending xx)
- NAI – check out with adjacent BA's
- Generation
- Load = Generation – NAI
- NERC Inadvertent = Inadvertent Interchange (II)
  - NAI – NSI
- Primary Inadvertent Interchange (PII) due to control error
  - (1-Y)*(IIactual – B*ΔTE/6)
  - Accumulated PII is paid back over next three hours via ATEC
- Did we follow the PLAN?

Transmission Operator

- The entity responsible for the reliability of its “local” transmission system, and that operates or directs the operations of the transmission Facilities
- Transmission Operator Area
  - The collection of Transmission assets over which the Transmission Operator is responsible for operating

Transmission Operator

- Outage coordination
- Real-time switching
- Voltage control
- Secure operations
- Forced outages and restoration

Reliable Operation

- N – 1 Criterion
- System must be able to suffer any credible contingency
  - No cascading outages
  - Stable – voltage and transient
  - No System Operating Limit (SOL) exceedances (WECC)
- Definition of “credible” contingency is open to some interpretation
  - Transmission Operator defines “credible” contingency
  - Varies depending on time horizon
  - Any single outage – generator, transformer, line – 3P fault
  - Credible multiple (N-2) – double circuit tower, breaker failure – LG fault

System Studies

- Thermal and voltage
  - Thermal overloading
  - High/low voltage
- Transient stability
  - Power system swings
  - Model fault impedance, relay times, breaker times
  - 3P faults for N-1
  - 1LG faults for N-2
- Voltage stability
  - Reactive margin
  - Voltage collapse
  - Does reactive switching help or not?

Operating Horizons - Seasonal

- Next peak season – Summer, Winter
- Studies based on worst case conditions
  - Peak loads
  - Peak generation – runoff in Northwest
  - Off peak
- Outage conditions studied to update procedures
  - Major transmission facilities, generators, etc
- Reliable operating points for outage conditions
- Usually conservative – guaranteed safe operating point
- Thermal/voltage, transient stability, voltage stability

Operating Horizons
Weeks, Next-Day, Real-Time

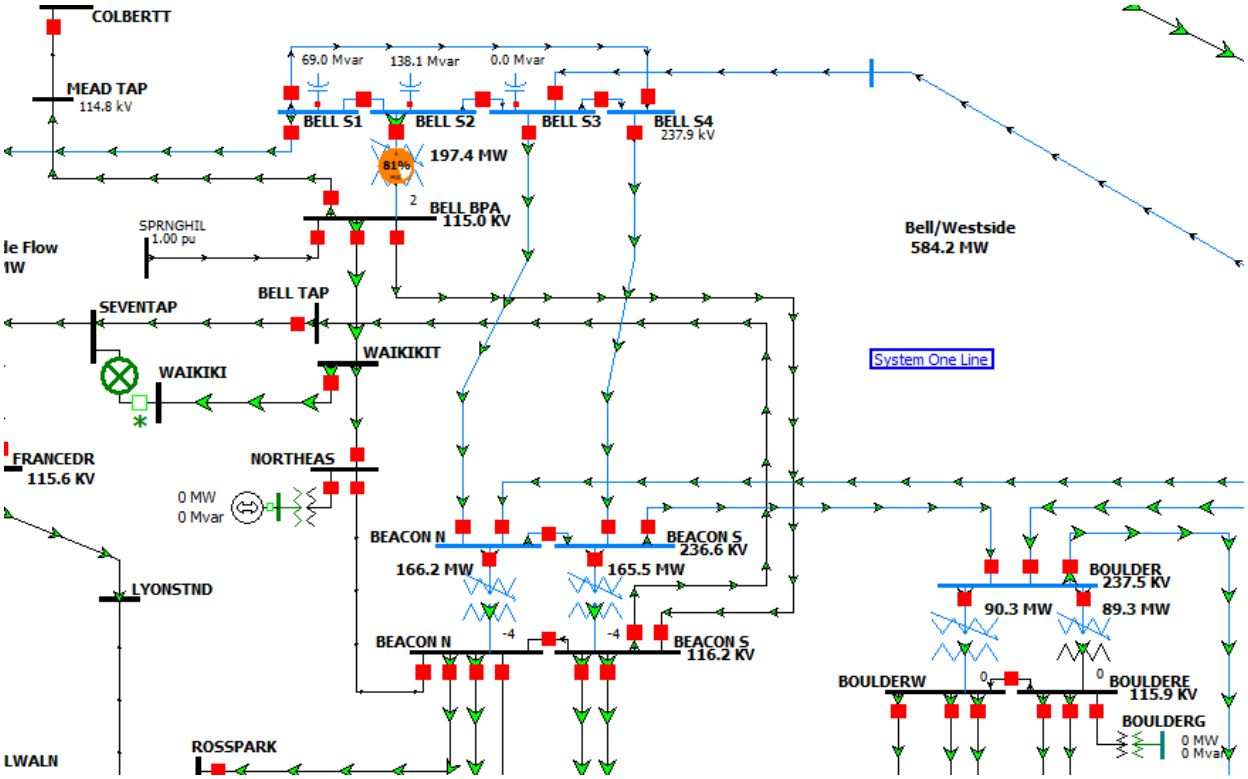
- Weeks Ahead
  - Outage coordination
  - Check thermal/voltage and voltage stability based on procedure limits
- Next-Day
  - Check thermal/voltage and voltage stability based on procedure limits
- Real-Time
  - State Estimation (SE) – Set powerflow model based on actuals
  - Real-Time Contingency Analysis (RTCA)
  - Check thermal/voltage, some voltage stability

N – 1 Criterion

- N-1 Criterion is based on present system
- When outage occurs (N-1), system then must perform for next outage (N-1-1)
- This is difficult – system is designed for N-1
- Rely on SE/RTCA to identify next problem
- N-1-1 does not equal N-2

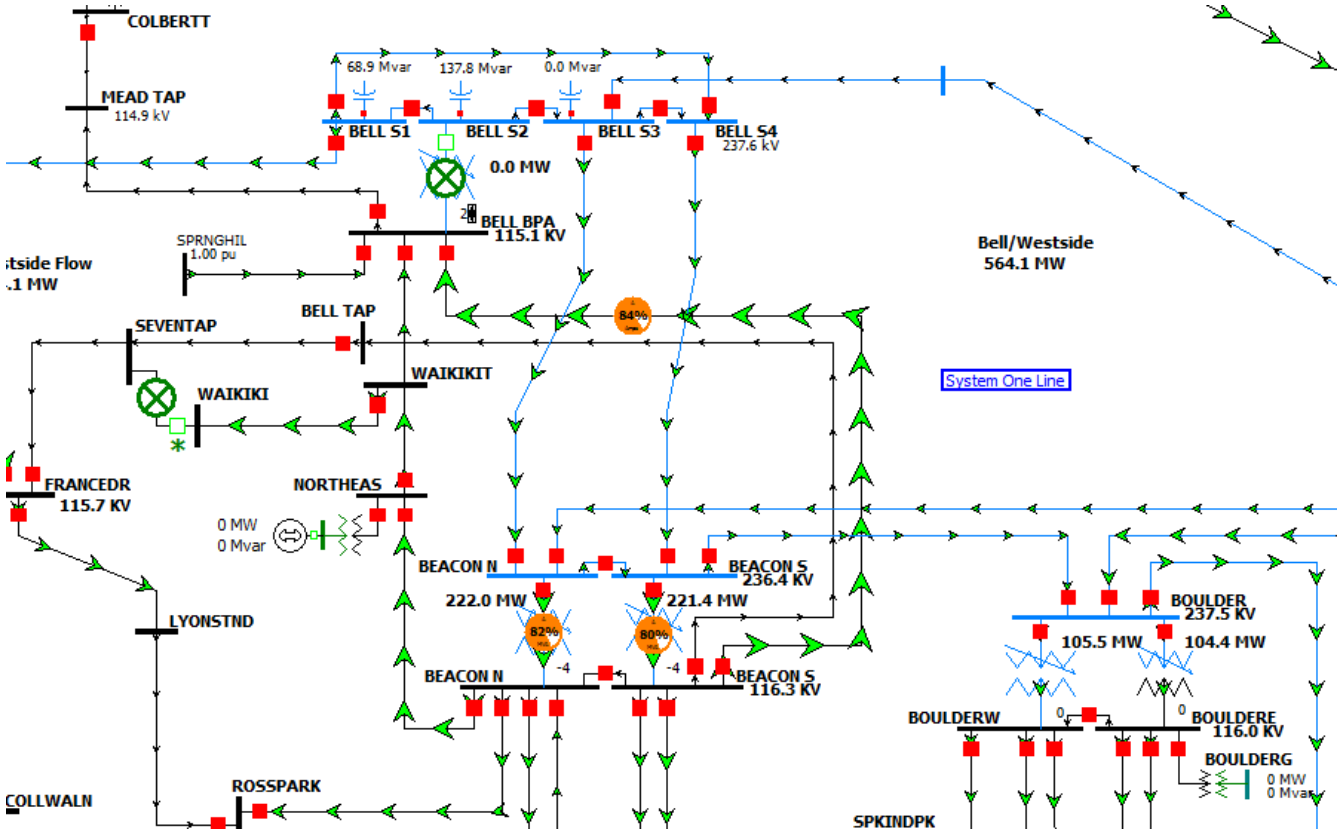
N-1-1 In Action

- N-0 All facilities in service – All is OK



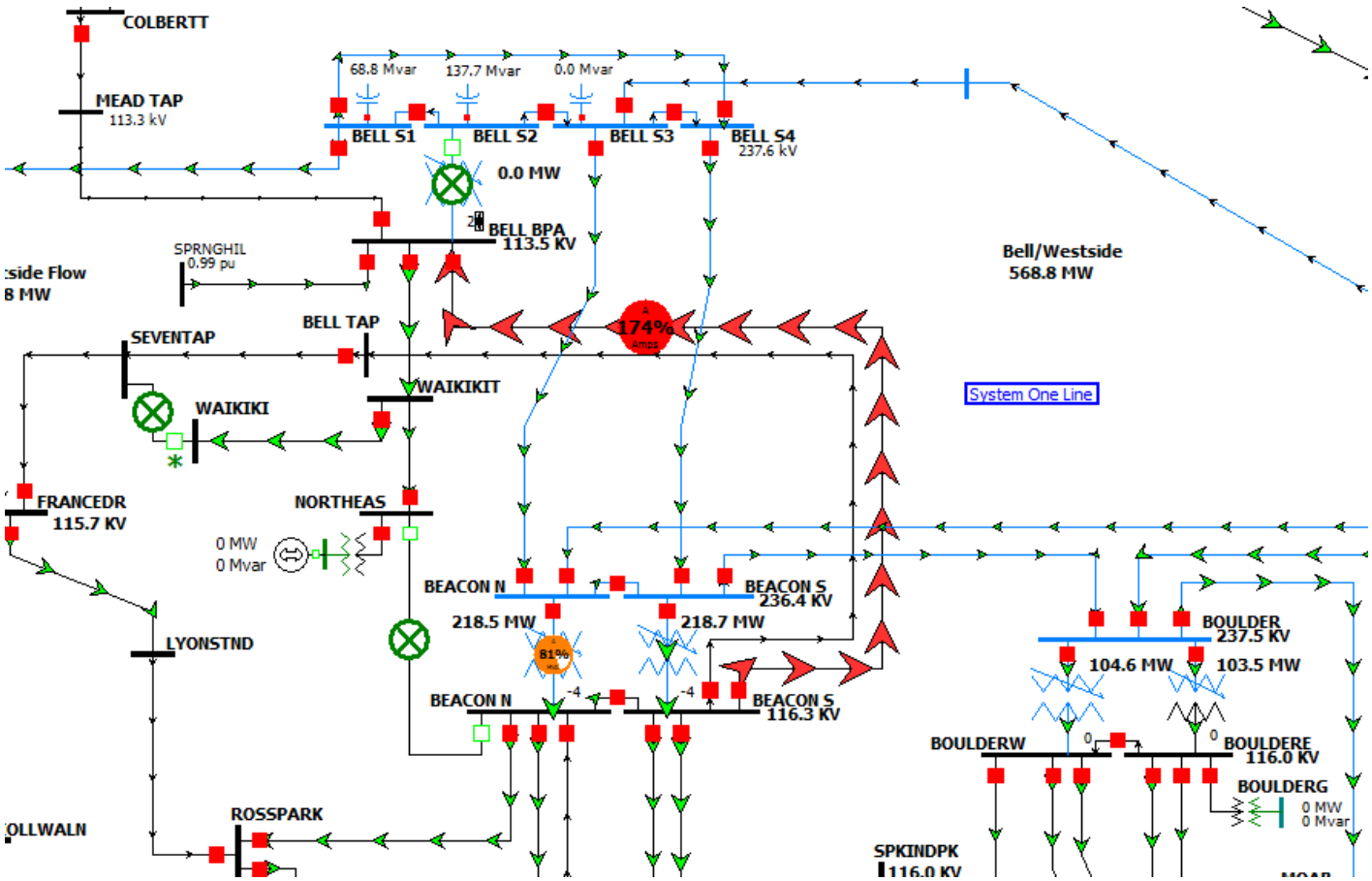
N-1-1 In Action

- N-1 Loss of 230/115 transformer – All is OK



N-1-1 In Action

- N-1-1 Loss of 115 circuit - All is NOT OK



N-1-1 In Action

- SOL exceedance is NOT acceptable post-contingency
- Pre-contingency mitigation is required
- Available actions
  - Radialize system if possible
    - We do this often to manage outages
  - Load shedding before the contingency occurs
    - This has been done, definitely to be avoided if possible
  - Change generation dispatch

N-1-1 in Action

- System is designed to absorb ONE credible contingency – Planning Scenario
  - N-1 – Category B
    - No post-contingency SOL exceedances allowed
    - Limited mitigating actions
  - N-2 or N-1-1 Category C
    - Post-contingency SOL exceedances allowed with mitigation
    - Load shedding, other actions permissible to mitigate
- System is operated with something always out of service – Operating Scenario

N-1-1 In Action

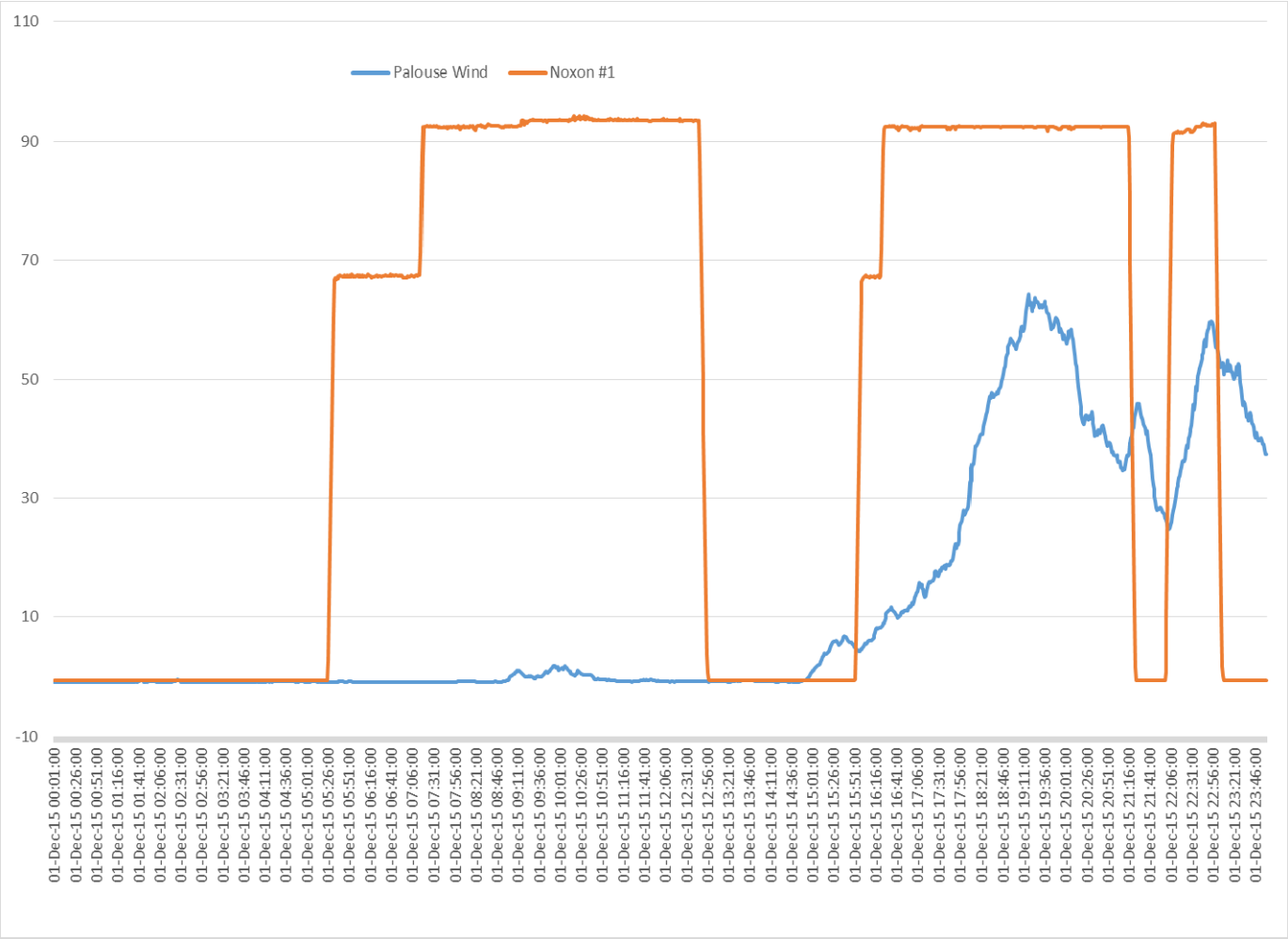
- Before March 2014 (WECC)
- N-1-1 SOL exceedances were handled with post-contingency action
  - Manual actions
  - Load shedding or loss acceptable
  - No cascading allowed
- N-1-1 Operations After March 2014 (WECC)
  - Same performance requirement as Planning Category B N-1
  - NO SOL exceedances are allowed post-contingency

N-1-1 In Action

- Reveals any weak links in the system
- This changes the system design philosophy
- Requires significant excess capacity or reduced planned outages
- Limits outage windows
  - Construction
  - Maintenance
  - Lots of spring and fall outages
  - Fewer summer outages
  - Fewer winter outages

Variable Generation Resources

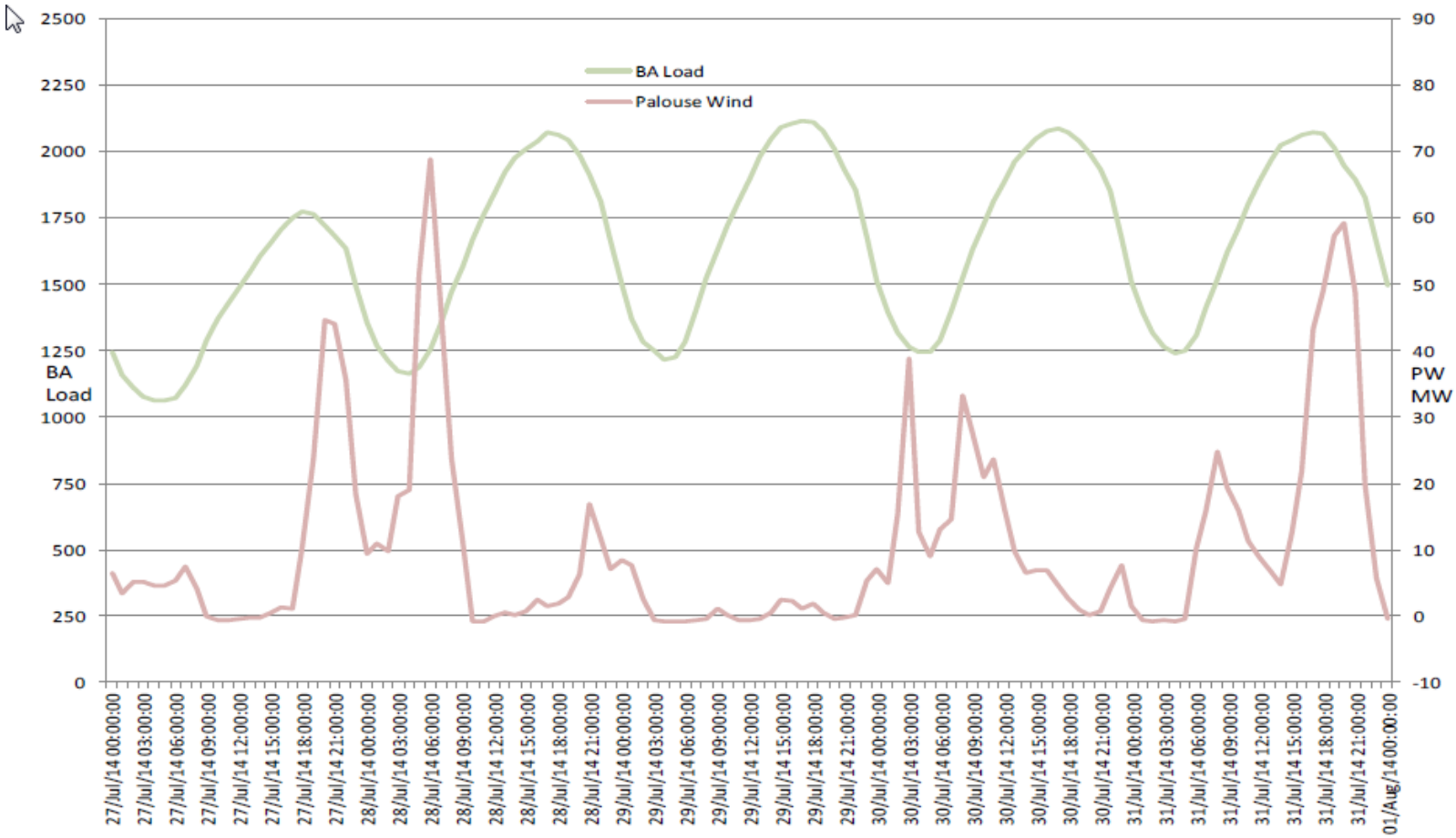
Variable Generation Resources



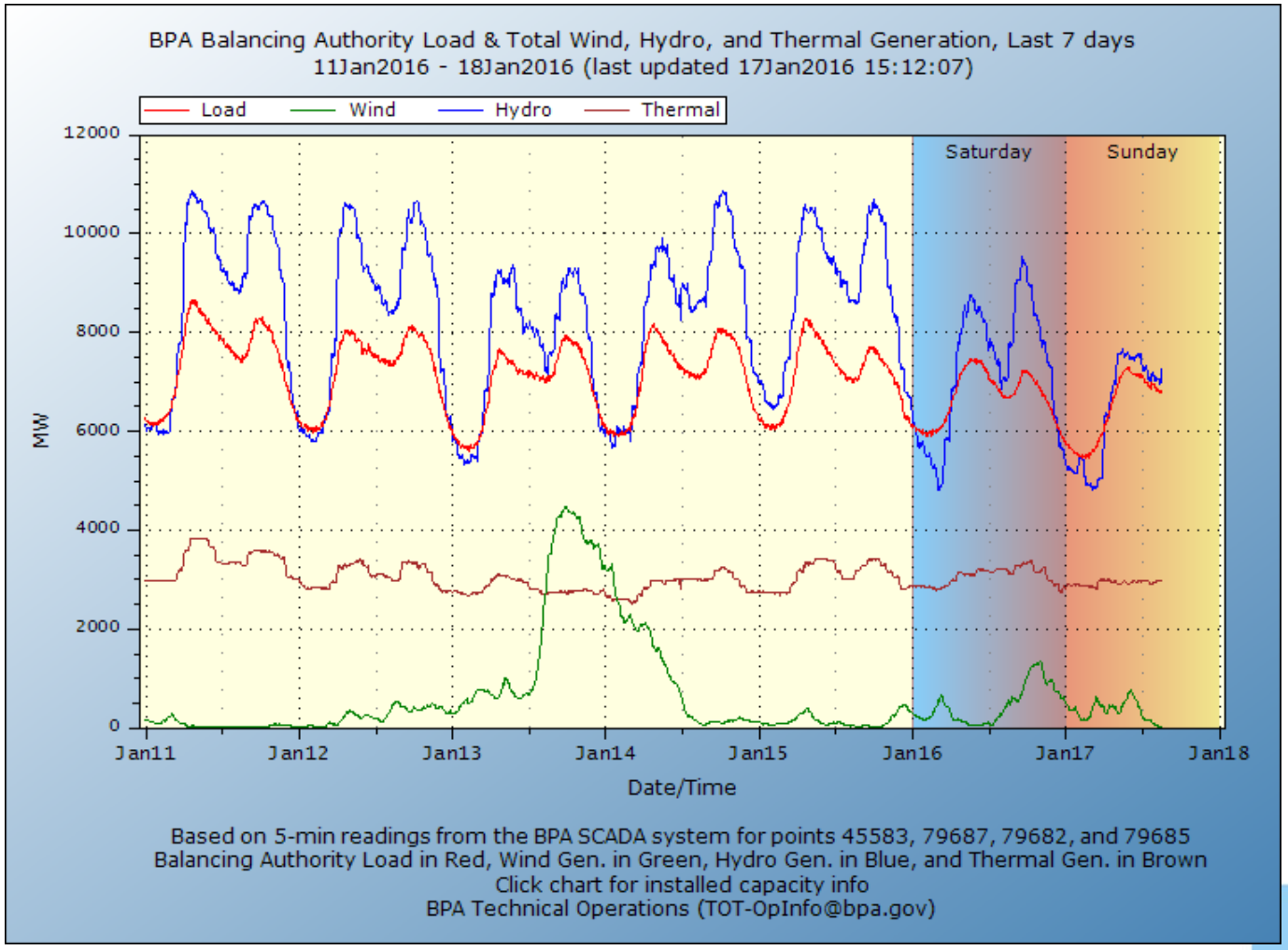
Variable Generation – BA Operations

- 100% known
  - Conventional generation dispatch
  - Net Scheduled Interchange
- 97% known
  - Load – forecasts are very good 24 hours out
- Not quite known
  - Wind generation
  - Forecasts are good, but get worse further out (two hours)
  - Can significantly increase regulating reserve required

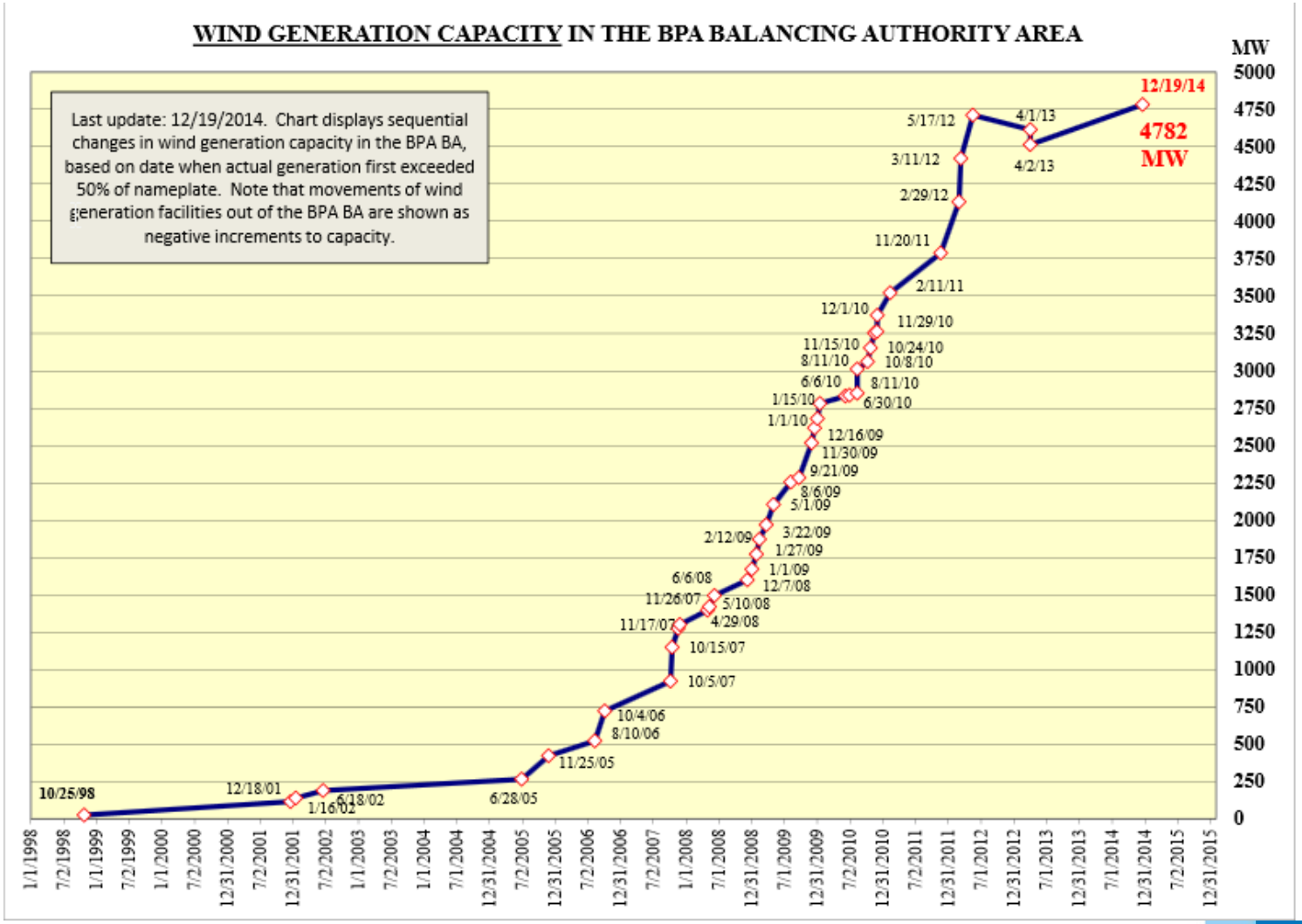
Variable Generation – Not always there when it is needed



Variable Generation



Variable Generation Growth



Questions?