Generation Initial Training Program

Telecommunications

PJM State & Member Training Dept.

Objectives

- Students will be able to:
  - Identify the various PJM communication protocols and procedures
  - Identify the various PJM communication tools
  - Identify the requirements of Member companies to have a plan for loss of Control Center Functionality
  - Identify NERC requirements for Generating Unit Complete Loss of Communication

Real-Time Data

- PJM and Member Companies analyze the security of the system using real-time information
- The model and results of PJM and the Member Companies network applications are only as accurate as the input data used in the calculations and modeling
  - Garbage in …. Garbage out
- Per NERC Standard IRO-010-2, under Requirement 1, PJM as the Reliability Coordinator, has determined and listed the data required in order to accurately monitor the security of the electric system

Data Exchange

- Data is exchanged between PJM and the MOC, TO, LSC and Marketing Center, other RTOs, and LSEs and Marketers for the following services:
  - Generation Scheduling
  - EMS
  - Historical EMS Data
  - Energy Transaction
  - Long-term Planning
  - PJM Administration

Data Exchange

PJMnet Communications System

- Primary wide-area network for communicating Control Center data to and from PJM
- Supports two communication protocols:

Inter-control Center Communications Protocol (ICCP)

- International standard for real-time data exchange within the electric power utility industry. It is intended to support inter-utility real-time data exchange which is vital to the operation of interconnected systems.
- Connects with Member Control Centers and qualifying generating plants over PJMnet

Data Exchange

JetStream

- Data system to connect remote assets and PJM to satisfy real-time, market and other data transactions
- Small generators, load response assets and other market participants can communicate with the PJM EMS through the Jetstream system
  - The connecting network is the Internet and the data protocol is DNP3
  - High levels of security are provided

Data Exchange

- EMS/GMS data is exchanged periodically on one of several fixed cycles, as well as on demand, by exception, and interactively

Cyclic Data

- Sent from Member Companies to PJM includes data needed for:
  - PJM control programs
  - Monitoring generation
  - Monitoring transmission
  - Monitoring interchange
- Sent from PJM to Member's EMS/GMS includes:
  - System control data
  - Generation & transmission information required for monitoring & SA programs
  - Area Regulation data

Data Exchange

Fast Scan Rate

- Used to develop ACE and Regulation values
- Sent every 2 seconds

Slow Scan Rate

- Used to develop dispatch control values, security monitoring and data tracking
- Sent every 10 seconds

Hourly Data

- Accumulated energy values

Data Exchange

- **Data exchanged by exception, on demand or interactively:**
  - Breaker, disconnect, and line status changes
  - Emergency messages in text format
- **Data Accuracy**
  - PJM Members are responsible for the accuracy of the data they send to PJM
    - Max of 2% overall inaccuracy

Data Requirements

Analog Data measurements required

- Bus voltages 34 kV & above
- MW & MVAR values for individual generating units > than 1 MW
- MW & MVAR values for designated transmission facilities at 69 kV & above (for single-phase metering, B-phase is preferred)
- Transformer phase angle regulator (PAR) taps
- Transformer load tap changer (LTC or TCUL) taps
- MVAR values for synchronous condensers
- MW & MVAR injections on buses at 34 kV and above
- Selected station frequencies

Data Requirements

Status Data required

- Breaker and disconnect status
- Transformer fixed tap settings (change in no-load tap setting)

Metering Plan

Criteria	Real-Time Telemetry Requirements
Generators participating in the PJM market as capacity resources	Real and reactive power
Generators 10 MW (Maximum Facility Output) or larger	Real and reactive power
Generators greater than 1 MW (Maximum Facility Output) and connected at a bus operating at 50 kV or greater	Real and reactive power
Solar parks 3 MW (Maximum Facility Output) or greater	Real and reactive power (see Section 12.2 for additional requirements)
Distributed generators (such as, the treatment of many units dispersed over a wide area as one aggregated unit) modeled less than 10 MW (Maximum Facility Output)	Real and reactive data at the BES injection point of accuracy within 10% of hourly MWh settlements data (revenue meter or accumulator data)
Public Distribution Microgrid Generators	Real and reactive power Status of Public Distribution Microgrid (connected to or disconnected from grid)
Generators that will also participate as PJM demand response resources when they will reduce load and have PJM-approved interconnection rights to inject power.	Real and reactive data, based on the Generator criteria in this table, at the point of interconnection and real and reactive power for the generators.

Categories of Data

Real-Time Data

- Instantaneous information
- Data required by PJM that determines:
  - System Security
  - Stability
  - Congestion
  - LMP

Non Real-Time Data

- Revenue information needed by PJM's applications and systems
- Determine Grid Accounting and Energy Interchange, such as Power Meter

Real-Time Data

Real-Time Data

- Instantaneous Net (+/-) MW and MVAR for each unit, measured on the low-side of generator step-up transformer
- Distributed generators modeled at less than 10 MW to provide Instantaneous Net (+/-) MW and MVAR at aggregation point based on an agreed upon algorithm
- Additional transmitted data may include:
  - Bus voltages and circuit breaker status, and other data

Data Requirements

Non Real-Time Data (Hourly Compensated)

- MWh delivered and received for each unit
- MVARh delivered and received for each unit*

***Note:** The MVARh revenue information is not currently required

Data will be considered a requirement in the event that PJM implements a Reactive Power Market

Precision Requirements

Real Time Instantaneous Data Sent To PJM	
Frequency	1/1000th of HZ (i.e. 60.001 Hz)
Voltage	1/10th of kV (i.e. 69.1 kV)
Real Power MW	1 MW integer (i.e. 52 MW) required, but PJM will accept greater precision if available
Reactive Power MVAR	1 MVAR integer (i.e. 42 MVAR) required, but PJM will accept greater precision if available
Current State of Charge (Energy Storage Resource Model Participant Only)	MWh remaining
Real Time Instantaneous Data Sent From PJM	
Individual Unit MW base point from Security Constrained Economic Dispatch (SCED)	1/10th of MW (i.e. 323.1 MW)
Regulation Signal (AR)	1 MW integer, + or – (i.e. 10 MW) but PJM will send smaller signals to certain sites such as renewable resources, etc.
Revenue Data Sent To PJM	
MWh Delivered and Received	1/1000th of MWh (i.e. 20.001 MWh)
MVARh Delivered and Received	1/1000th of MVARh (i.e. 15.002 MVARh)

Manually Entered Data

What is it?

Data that is manually entered and updated by the System Operator

- Steps:
  - Identify suspected data
  - Verify validity of suspected data
    - Use other tools, experience & knowledge, other computer models if available
  - Sanity check – Utilize bus summation calculations
  - Determine requirements for updating
    - (For 345kV & higher RTU or tie lines, 30 minutes, Manual 3)
  - Resolve cause of bad data

Manually Entered Data

Keeping on top of Manually Entered Data

- Start of Shift:
  - Identify points that are currently updated manually
    - Shift turnover sheet or pass down from previous shift
    - EMS displays that summarize manually replaced data
- During Shift:
  - Monitor system for additional bad data
  - Take necessary action to correct data when found
  - Update values or status of current manually replaced data
- End of Shift:
  - Inform your relief of all points currently manually entered

Data Requirements – Intermittent Resources
Wind Power

Initial Data Requirements

- General turbine information
- Class of turbine
- Capacity of turbine
- Power generation threshold rates (i.e. min/max wind speed)
- Manufacturer power curves of individual wind turbines
- Geographic location (longitude and latitude) of site or each turbine if available
- Hub height of wind power facility

Initial Data Requirements *(Cont.)*

- Aggregate historic data for existing facilities connected to PJM or bid into PJM market
  - Measured MW output
  - Outage information
  - Wind speed at hub height
- Ambient temp operation limits
  - Information on “cold weather packages” installed

Real Time Data

- Aggregate real time output
  - Low side and high side net generator MW
- Real time meteorological data
  - Must have at least one tower
    - Or wind speed and direction from selected turbines anemometers and wind vanes
  - Height should be same or close to hub height of turbine
    - Calibrated annually
  - Depending on topology and accuracy of the Wind Power Forecast, PJM may require additional towers at a site
  - All data items, regardless of type, shall be collected and disseminated at a frequency of 10 seconds or less

Real Time Data

Parameter	Units	
Wind Speed	meters/second	Required
Wind Direction	decimal degrees from true north	Required
Temperature	Fahrenheit	Required
Pressure	Hectopascals	Required
Humidity	percent	Accepted

Data Requirements – Intermittent Resources
Solar Power

Initial Data Requirements

- AC installed capacity (Maximum facility output) of the plant (MW)
- DC installed capacity of plant (MW)
- For fixed panel sites:
  - Azimuth angle of panels (decimal degrees from true north)
  - Altitude angle of panels (decimal degrees from horizontal plane)
- For tracking sites:
  - Tracker type (single or dual axis)
  - Tracker make and model

Solar - Initial Data

Initial Data

- Geographic location of center point of solar park site (decimal degrees longitude and latitude)
- Geographic location of meteorological data sensors (decimal degrees longitude and latitude)
- Manufacturer and model of the PV panels
- Aggregate historic data (measured MW output, outage information, irradiance, and temperature) for existing facilities that connect to PJM Transmission or bid into the PJM market
- Aggregate Reactive Capability Curve (D-Curve) is required to ensure accuracy of PJM's EMS Security Analysis Results

Solar - Real Time Data

- Solar parks greater than or equal to 3 MW (Max Output), regardless of voltage level of connected bus, are required to provide the real-time solar park MW/MVAR output along with other data points
  - This output should be telemetered at low-side gross
  - High-side net may also be required as dictated by PJM's model
- If a solar park is collocated with an energy storage facility such as a battery, then separate metering is required for each component in order to preserve solar forecast accuracy

Solar - Real Time Data

- Real Time Meteorological Station
  - Forecasting accuracy is dependent on the availability of the real time meteorological station data
  - Each solar park must install at least one meteorological station in the park to provide real time data to PJM through an ICCP or DNP link
  - Based upon topology and accuracy of the forecast, PJM may request the addition of more meteorological stations at a site
  - The generation owner should calibrate and check the accuracy of the meteorological station annually

Real Time Data

- Real time output
  - Provide real-time solar park MW/MVAR (Low-side gross)
  - If park is collocated with a energy storage facility, separate metering is required to maintain accuracy
- Real time meteorological data
  - Must have at least one meteorological station in the park
    - Or wind speed and direction from selected turbines anemometers and wind vanes
  - Depending upon the topology and the accuracy of the solar power forecast, PJM may request addition of more meteorological stations at a Solar Park site

Real Time Data

Parameter	Units	Requirement or Accepted
Irradiance	Watts/meter^2	Required for plants with Maximum Facility Output of 3 MW or higher
Back Panel Temperature	Fahrenheit	Required for plants with Maximum Facility Output of 3 MW or higher
Ambient Air Temperature	Fahrenheit	Accepted
Wind Speed	meters/second	Accepted
Wind Direction	decimal degrees from true north	Accepted

Coordinating Telemetry and Equipment Outages

Data Outages

Miscellaneous Reportable Outages

- Email coordination notice 24 business hours in advance of regular system changes that could affect ICCP data link communications or the data exchange with PJM
  - Any action affecting ICCP data sent to PJM (EMS/GMS Database updates, server failovers)
  - Significant Software Enhancements
  - Communication line outages
  - Backup center testing
  - Failovers to alternate sites
  - Network and Firewall maintenance
  - RTU outages or changes to RTU data sent to PJM for RTUs connected to EHV (345kv and above) facilities

Data Outages

Miscellaneous Reportable Outages

- The PJM EMS Networking group will coordinate any technical details, additional support, etc. with the member company
- Members providing notification should send it to the following email address (outage@pjm.com). In an emergency, call the PJM Support Center at 610-666-8886 or the Dispatch Supervisor at 610-666-8806
- The notification should include:
  - The action being taken by the member company
  - Planned length and expected time of the outage
  - Potential impact to PJM
  - Member contact information
- Member Company System Operator should coordinate final outage with the PJM Dispatch Supervisor 15 minutes prior to the event

Data Outages

Scheduling Data Outages

- PJM staff has the authority to:
  - Reschedule or cancel a member company scheduled planned outage based on system conditions or existing ICCP data link outages
  - Deny a request for a member company planned outage if requested time has been previously scheduled
- PJM will notify member companies of PJM initiated outages via an email list at least 24 business hours in advance
- PJM will follow-up significant outages with an All Call message 15 minutes prior to the outage

Data Outages

Scheduling Data Outages

- The following time periods are not allowed for planned outages:
  - During specific resource critical times including PJM quarterly model build days, due to heightened operational and technical complexity and risk
  - During other unique and infrequent major events for PJM, such as major EMS upgrades or major company integrations
  - Over holidays, due to constrained resource availability
  - During multiple company ICCP data link outages (No more than one member company planned outage will be accepted in any given time period)
  - Further restrictions may be enforced when peak load operations are projected in any Control Zone

Data Outages

Scheduling Data Outages (con't)

- Unscheduled system changes or events that could potentially affect data received by or sent by PJM must be immediately communicated
- To the extent possible, emergency changes should occur:
  - Prior to 11:00 EPT during summer operations
  - Between 10:30 – 14:30 EPT during winter operations
  - If emergency work that cannot be delayed or rescheduled requires an outage, the PJM Shift Supervisor will work with the emergency coordinators for approval and scheduling

Data Outages

Unscheduled Data Outages - Considerations/Actions (TO/GO):

- Contact PJM Dispatch to report/discuss problem
- Contact the support staff to resolve the issue
- Provide a contact person and phone number to PJM Dispatch to enhance efficiency of communications avoiding potential reliability issues
- Notify PJM Control Room when system has returned to normal

Data Outages

Unscheduled Data Outages – Additional GO Considerations/Actions:

GO Operator – MOC Operator

- Recognize previous SCED approved base-points are stale while ICCP link problems exist
- Verbally communicate manual dispatch directions to plants if communication problems are not resolved within 10 minutes
- Log manual dispatch direction

Data Outages

Unscheduled Data Outages – Additional TO Considerations/Actions:

TO (Operator)

- Contact PJM Dispatch regarding transmission constraints
- Staff critical substations to support transfer of critical data to PJM

Data Outages

Unscheduled Data Outages – PJM Generation Considerations/Actions:

- Recognize previous SCED approved base-points the member is receiving are stale
- Communicate zonal cost if problems are not resolved within 10 minutes
- Communicate targeted generation dispatch if transmission constraints arise
- Log manual dispatch direction
- Reassign regulation to other MOC units as necessary
- Elevate PJM/MOC communication to Shift Supervisor level if reliability issues arise

Data Outages

Unscheduled Data Outages – PJM Transmission Considerations/Actions:

- Communicate impact on ability to monitor transmission system
- Update EMS with the critical data provided by the Transmission Owner
- Manually redispatch, as necessary, to control transmission constraints based on the Transmission Owner's analysis
- Ensure all actions are logged

Data Outages

- Data Exchange during EMS Datalink Outages
  - Members are responsible for determining data quality indicators for all data transmitted to PJM
    - Failed individual values and any value calculated using a failed point must be flagged
    - State estimated values may suffice for an interim period
  - If PJM encounters any real-time data quality issue that affects Real-time Assessments, PJM will notify the Member via email or phone call to address the issue
  - Members shall send data to PJM during planned and unplanned outages based on the type of outage, the available alternative communication method and the thresholds for reporting

Data Outages

- The following are acceptable alternate methods of communication based on the outage type:
  - RTU/Device Outages (when the ICCP/DNP3 communication is up, but a specific data set is lost due to RTU or telemetry device outage)
    - Member shall manually replace the failed data within their EMS, which is communicated to PJM automatically via the existing EMS data link
    - Member shall call the PJM Control Room to verbally communicate the failed measurement data needed by PJM Control Room
    - Member shall securely transfer measurement data files using a mutually acceptable transfer protocol

Data Outages

- The following are acceptable alternate methods of communication based on the outage type:
  - EMS Link Outages (when the data link is down and all incoming EMS data from the member is telemetry failed):
    - Member shall securely transfer measurement data files using a mutually acceptable transfer protocol
    - Member operator shall call PJM control room to verbally communicate the measurement data

Data Outages

- If using an automated or manual electronic alternate method of communication, the PJM Member shall follow the procedure below:
  - The following measurement data shall be updated at least every 30 minutes via manually entered values or via the secure data file transfer:
    - Tie Line Flows, both internal and external
    - Transmission MW and MVAR flows and bus voltages at ≥ 100 kV
    - Generation MW and MVAR flows at ≥ 25 MW capacity

Data Outages

- If using an automated or manual electronic alternate method of communication, the PJM Member shall follow the procedure below:
  - If the PJM Member is using the secure data file transfer method, the measurement data file shall include the following information:
    - Equipment name
    - Measurement description
    - ICCP Object ID (if applicable)
    - Measured value
    - Timestamp

Data Outages

- In addition, if a significant event as described below occurs, the Member shall verbally notify the PJM Dispatch Office:
  - The loss of any equipment ≥ 100kV
  - A change of ≥ 25 MW of any generator MW flow
  - A change of ≥ 100 MW flow at ≥ 500kV
  - A change of ≥ 50 MW flow at < 500kV
  - A transformer tap position change occurring at ≥ 230kV
  - A breaker status change at ≥ 100kV
- If the actual values cannot be given, provide the best data available

Data Outages

- If the Member is unable to send a secure transfer file or manually replace values, then the Member shall follow the procedure below:
  - The Member shall check every 30 minutes for significant system changes compared to the last measurements verbally or electronically communicated to PJM Dispatch
    - If there are, the Member shall call PJM Control Room to verbally communicate these changes
    - If the actual values cannot be given, provide the best data available
  - Significant changes include:
    - The loss of any equipment ≥ 100kV
    - A change of ≥ 25 MW of any generator MW flow
    - A change of ≥ 100 MW flow at ≥ 500kV
    - A change of ≥ 50 MW flow at < 500kV
    - A transformer tap position change at ≥ 230kV
    - A breaker status change at ≥ 100kV

Impacts of Bad Data

What are the impacts?

- Safety of personnel
  - Energized vs. De-energized
- Reliability
  - Uninterrupted Operation
    - Overloaded lines lead to outages
    - State estimator and Security analysis results incorrect.
    - Violation of limits (Actual, LTE, STE or Load Dump)
- Economy
  - Operating the system at the least cost
    - Bad SE / SA results could lead to unnecessary out-of-merit operation

Impacts of Bad Data

What are the impacts?

- Localized
  - MWH readings for large customers
  - Single value in substation or entire substation
- Company Wide
  - Communication links down with control centers
- System Wide
  - Economic dispatch not followed (ACE not on zero)
- Interconnection Wide
  - Inaccurate net tie flows

Examples

Homer City

Impacts of Bad Data Examples

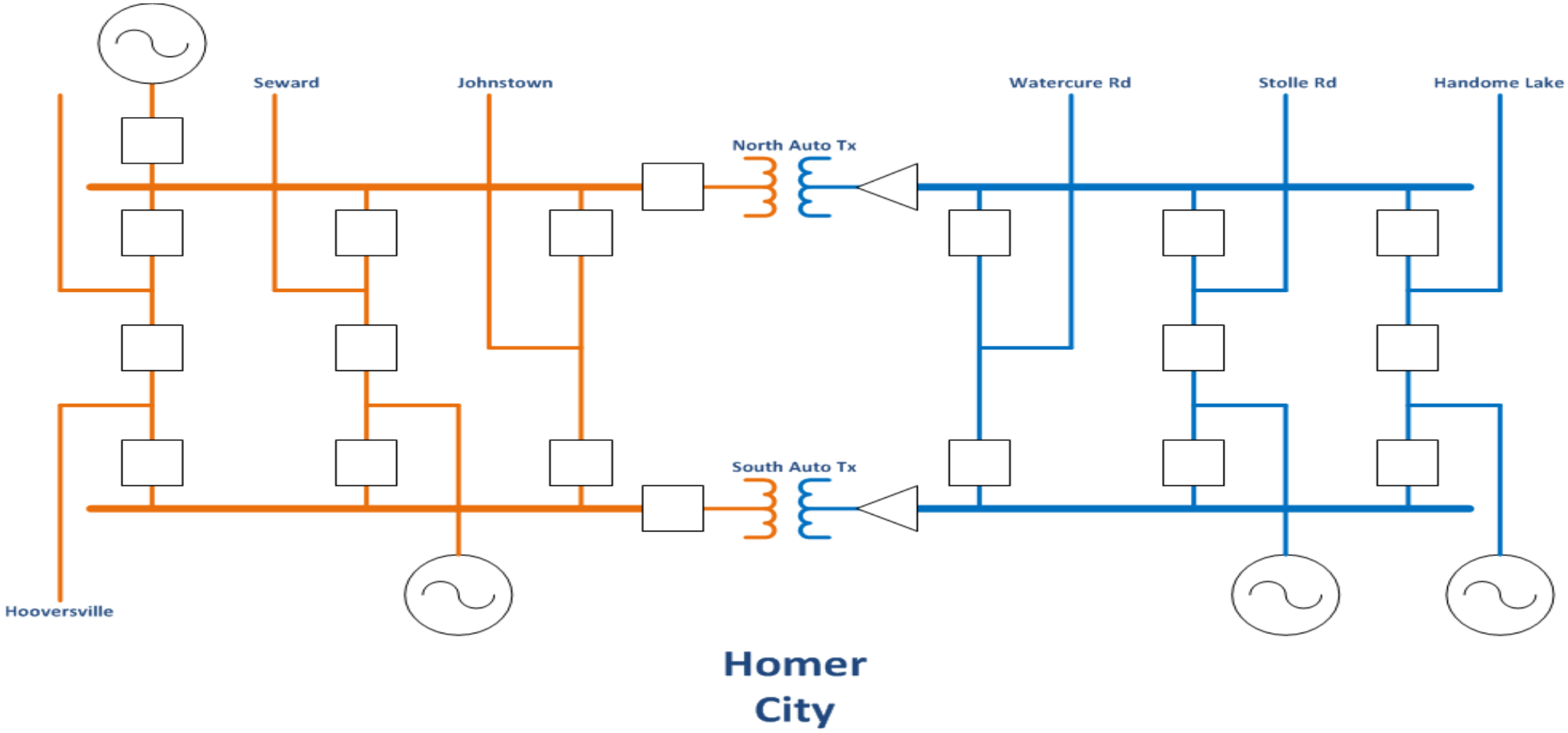
Homer City South 345/230 Auto Transformer CB

- MW/MVAR reading for South Auto Transformer was identified as being incorrect
  - Problem started 3/31/2006 @ 13:30
- While awaiting repair by field personnel, TO manually replaced the points and updated them on a periodic basis
- During one update the low side CB was inadvertently manually replaced in the closed position
  - Location of MW value in relation to CB was very close

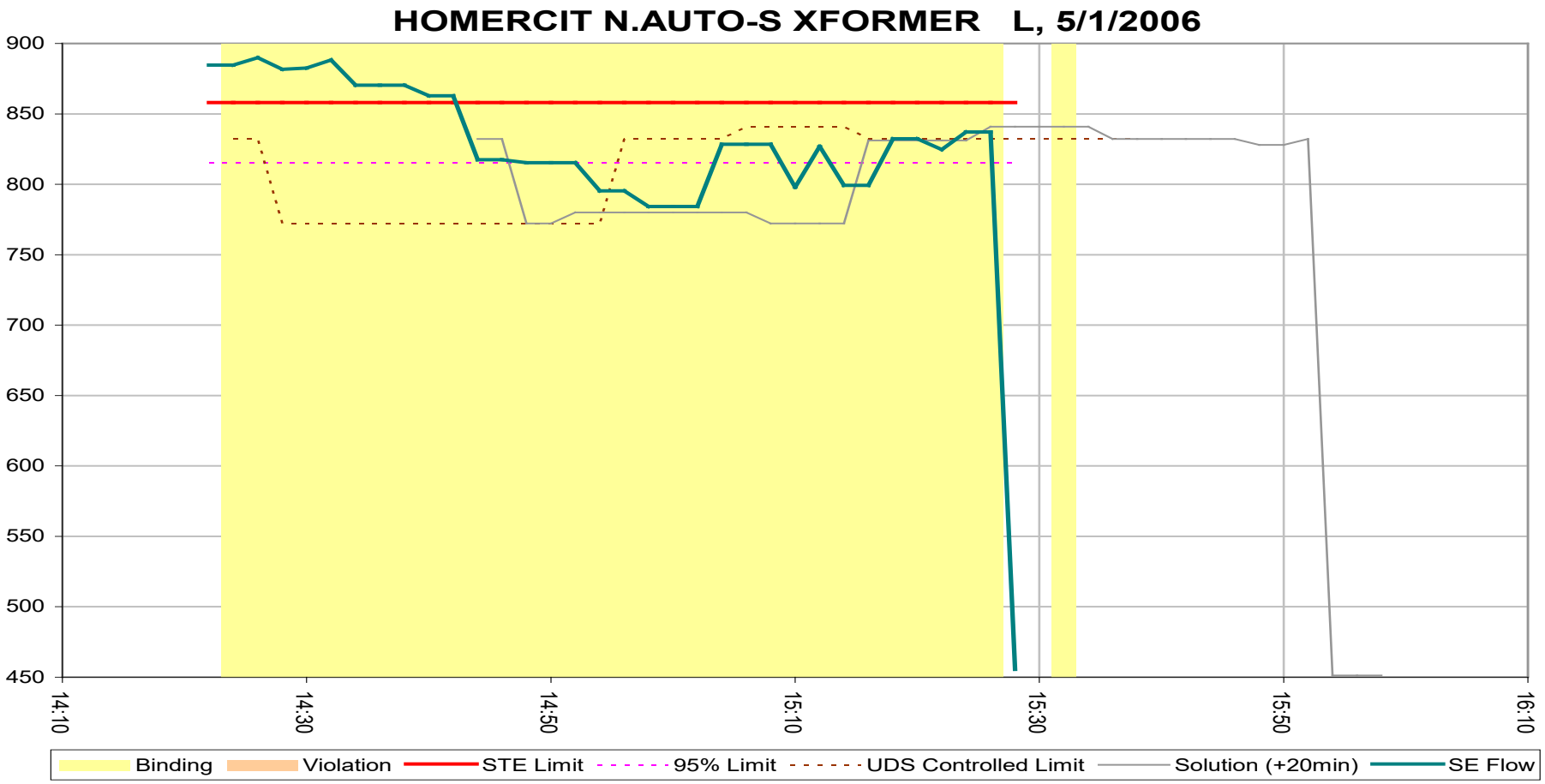
Impacts of Bad Data Examples

- South Auto Transformer 230 kV CB tripped open on 4/29/2006 @ 22:36
  - No indication to TO due to status and MW/MVAR points being manually replaced
- As a result, contingency analysis results for Homer City North Auto Transformer were inaccurate until the problem was corrected on 5/1/2006 @1700

Impacts of Bad Data Examples

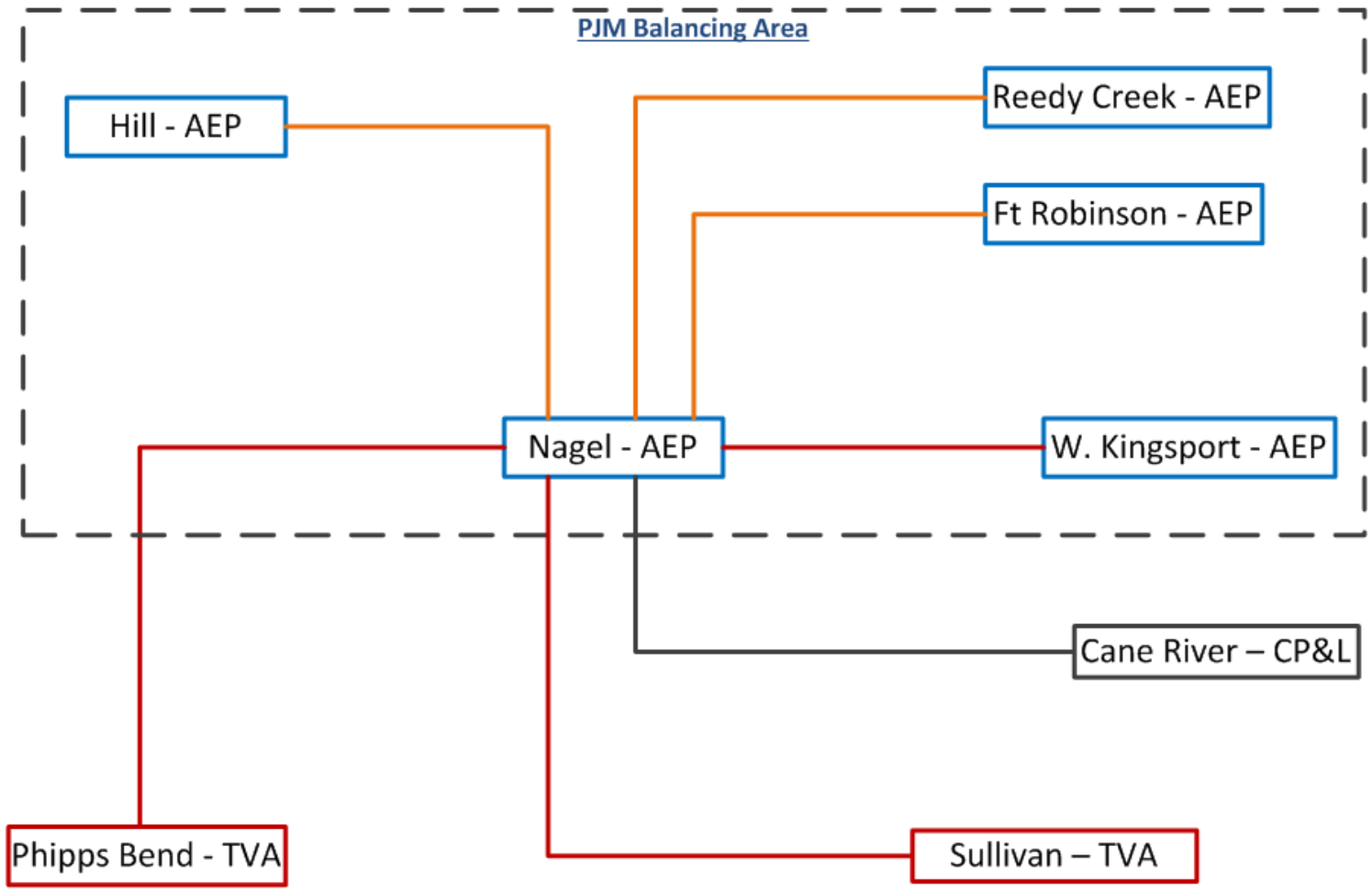


Impacts of Bad Data Examples



Nagel Ties

Impacts of Bad Data Examples

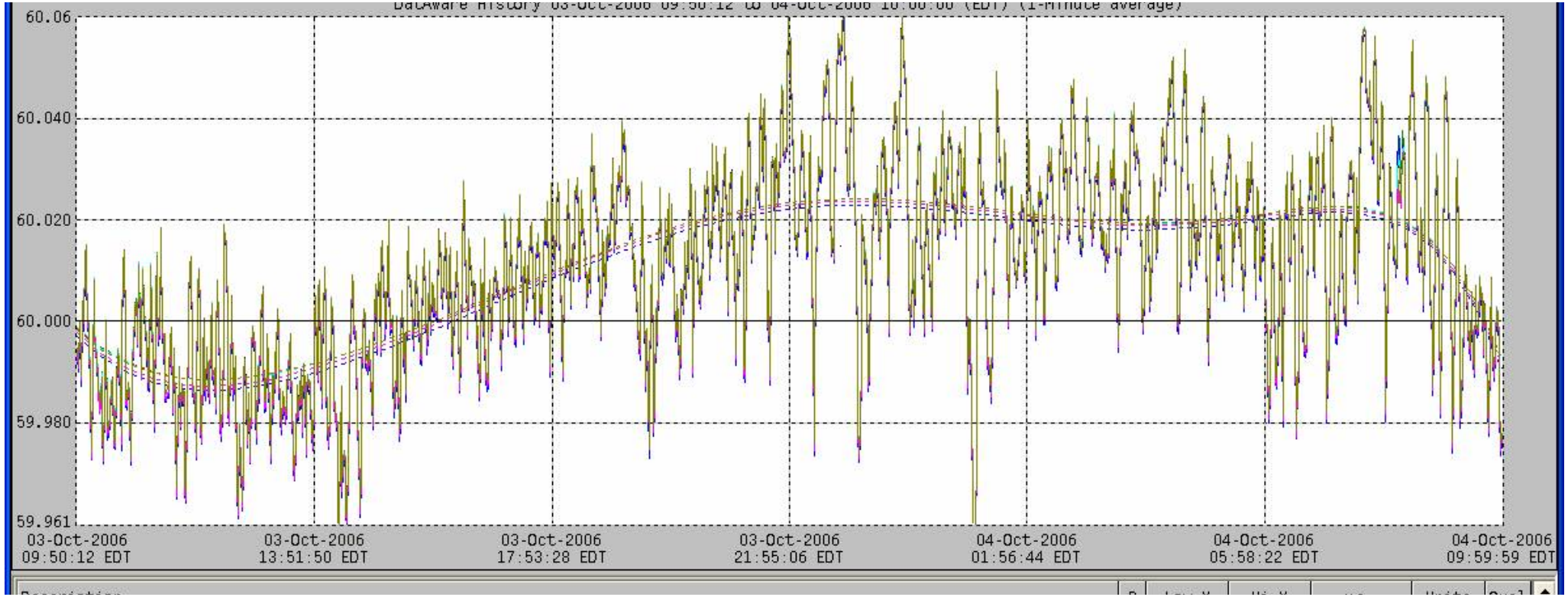


PJM began experiencing problems on the:

- Nagel-Phipps
- Nagel- Sullivan
- Nagel – Cane River
- Tie line values gradually drifted from actual values
- No sudden step changes that would have alerted operators

Impacts of Bad Data Examples

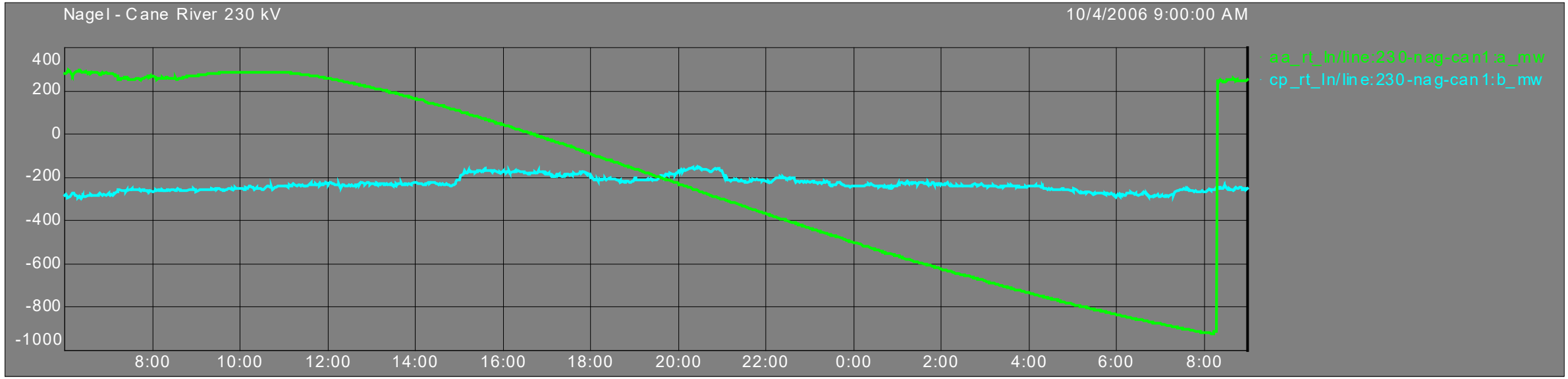
- The inaccurate tie values resulted in PJM over-generating between 10/3/2006 15:00-10/4/2006 09:00, contributing to high frequency for an 18 hour period

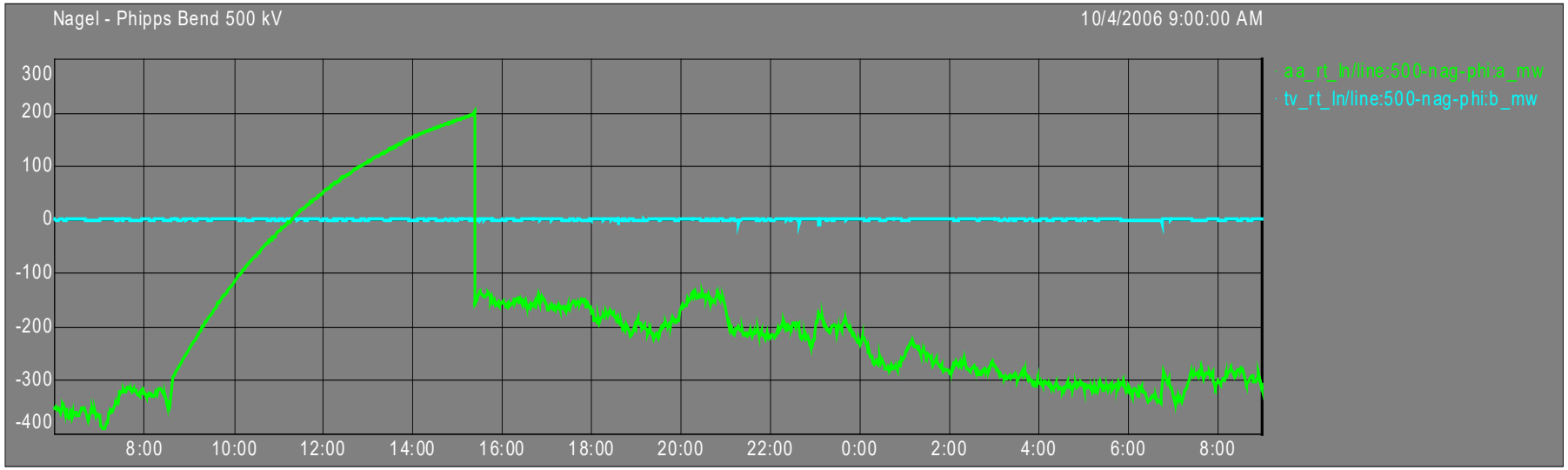


Impacts of Bad Data Examples

- At approximately 8:20 am on Oct 3, 2006 both the CPLW CANE RIVER and TVA NAGEL-PHIPPS Bend tie-line meters began reporting what appear to be incorrect values
- The Nagel-Phipps Bend line appeared to have returned to a correct value at 15:22 on Oct 3, 2006
- The Cane River tie appeared to have returned to a correct value at 8:20am on Oct 4th, 2006

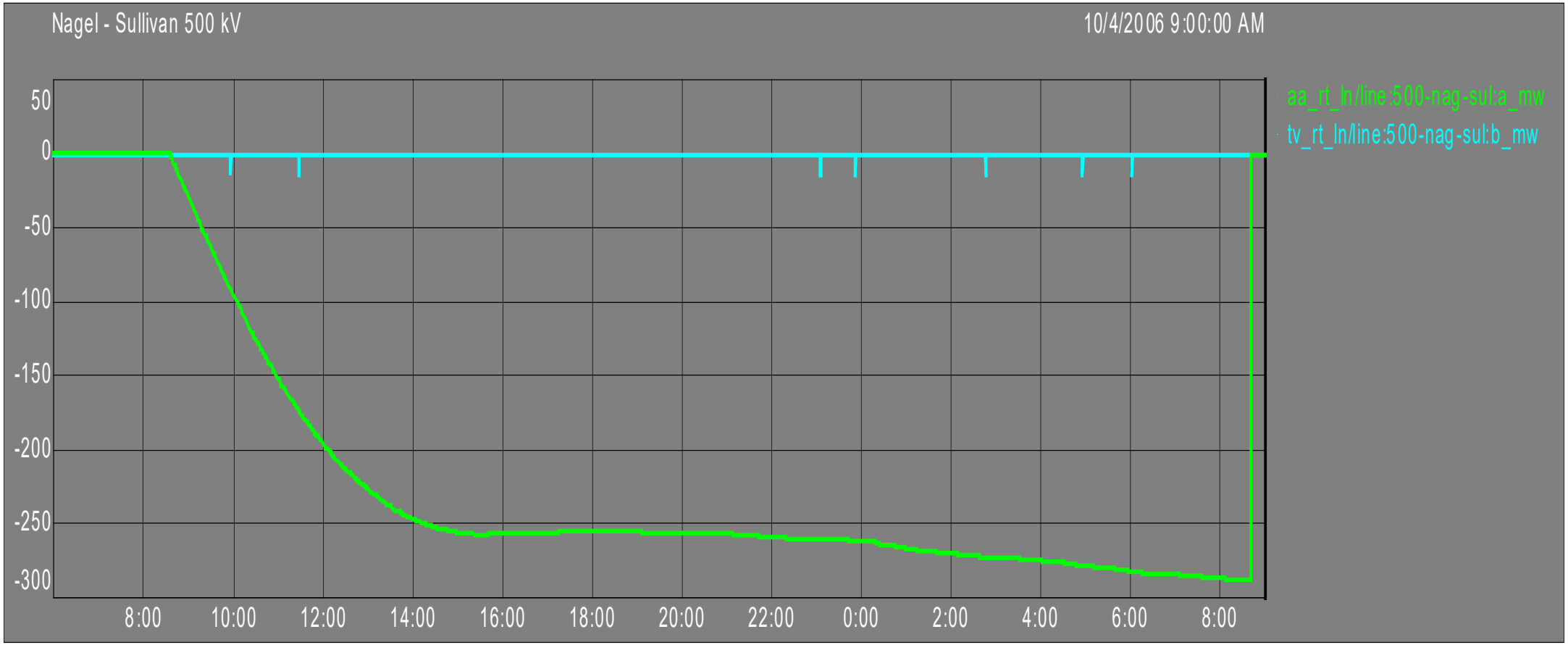
Impacts of Bad Data Examples





Impacts of Bad Data Examples

- In addition to this error, the Nagel Sullivan tie also began reading a bad value during the same time period



Impacts of Bad Data Examples

- While changing the RTU configuration at Nagel Station, technicians inadvertently disconnected three cables affecting tie-line metering
  - Tie line measurements drifted slowly after cables were disconnected, this is a characteristic of the RTU when the MW input is left “open ended”
  - The AEP and PJM EMS relies on significant spikes (100 MW) in readings to generate a rate of change alarm

Impacts of Bad Data Examples

- AEP and PJM did not detect bad SE data for numerous hours
- PJM operators are responsible for reviewing bad data as part of shift turnover, operator did follow proper shift turnover procedures but did not detect the problem
- AEP support staff, not real time operators, review SE bad data during normal working hours
- The AEP Transmission Services Coordinator became aware of the problem when the meter error values increased significantly over a period of several hours
- AEP contacted maintenance personnel to look into the problem

EMS Cutover

Impacts of Bad Data Examples

FE RTU Cutovers

- Planned cutover from Siemens EMS to AREVA EMS to occur over a 2 day period (1st day was PJM holiday)
  - Numerous ICCP uploads were performed to update the source of analog data being sent to PJM
  - As cutovers progressed, the sign on several analog data items became mismatched between the PJM EMS and the PJM GMS

Impacts of Bad Data Examples

FE RTU Cutovers

- Thirteen data items going to the PJM GMS system needed an invert record to make them match the correct values going to the PJM EMS
- Some of the effects of the error were passed on to member companies through the EMS ICCP links
  - Affected the network applications of PL and PE

Impacts of Bad Data Examples

FE RTU Cutovers

- Numerous cable/RTU moves were performed over 1st and 2nd day
- Once FE had confirmed the integrity of the data on AREVA EMS they would perform an ICCP dB upload get the data to PJM
- PJM engineer would then verify the data and make note of any problems requiring corrective action

Impacts of Bad Data Examples

FE RTU Cutovers

- PJM personnel found mismatch on some data points in Penelec and informed FE of issues at end of 2nd day – 34 hours after start of cutovers
- PJM and FE engineers worked together to indentify 13 points that had incorrect sign being passed to PJM GMS
- Performed database upload to invert sign on values and correct issues

Impacts of Bad Data Examples

FE RTU Cutovers

- This was first of 3 planned EMS cutovers planned
- No formal procedures that outlined data verification process
- During future cutovers, points that needed invert applied were identified prior to start of data migration
- Additional checks to be made to ensure data quality is correct

Member Back-Up Control Center Requirements

- PJM Members are required to construct and man Control Centers
  - Subject to the criteria outlined in Manual 01, Section 2 – “Member Control Center Requirements”
- In addition, Manual 01, Section 2.5.6 specifies that each Member TO must have a plan for loss of control center functionality, which includes
  - Procedures and responsibilities for providing annual training
  - Ensurance that operating personnel are able to implement the plans

Member Back-Up Control Center Requirements

- All PJM Members shall develop a backup recovery plan to cover various contingencies,
  - Including maintaining an off-site storage location for updated copies of all software and data files necessary to restore control center functions
- The backup recovery plan is subject to review by PJM

NERC Reliability Guideline Intentions

- Incorporation of guideline practices are strictly voluntary, but reviewing, revising, or developing a program using these practices is highly encouraged
  - To promote and achieve the highest levels of reliability for the BES
- Not applicable to generation connected to asynchronous loads or systems not normally part of one of the Interconnections
- Not to be used to provide binding norms or create parameters by which compliance to standards is monitored or enforced
- Not intended to take precedence over any regional procedure

NERC Reliability Guideline Intentions

- Not meant to prevent generating unit operators from taking actions necessary to protect the equipment under their supervision from damage to include if necessary to be taken off line in a safe manner
- Protective equipment should not be bypassed or rendered inoperable in order to follow this guideline
  - Safety of personnel and prevention of damage to system equipment are the first responsibilities of electric system operators at all levels

Assumptions

- **Loss of Communications** – all data/voice communications are lost between the on-site generating unit operator and the System Operator for the Balancing Area, Transmission Operator and Reliability Coordinator
- **Generating Unit Status** – some generating capacity remains in service or can be brought into service locally at the plant operator's discretion, to serve the load over the period of lost communications
- **Instrumentation** – Generating unit are equipped with turbine speed sensors capable of 1 RPM increments and sometimes frequency metering devices capable of displaying (and optionally recording) system frequency on both narrow (roughly 59.95 Hz to 60.05 Hz) and wide (roughly 58.0 Hz to 62.0 Hz) ranges. Nomograms or other job aids that convert generator speed to frequency can be used.
- **Situation Awareness** – The on-site generating unit operators recognize that frequency is abnormal and a unique situation is occurring

Frequency Response

- With no communications available, turbine speed , which is proportional to frequency, is the only means available that a Generator Operator will have to control the system
- Deadband (Green Zone): As long as frequency stays close to 60 Hz, no control actions need to be taken
  - Deadband should be +/- 100 mHz (59.90 Hz to 60.10 Hz)
  - “Secondary Control” not to be confused with governor control

Frequency Response

- Selective Response (Yellow Zone): As frequency moves outside of the "deadband" area, frequency should be corrected using generation in a gradual manner
  - Response band between +/- 100 mHz and +/- 200 mHz (59.80 Hz to 60.02 Hz)
  - Ramp rate: 1% of the unit's ramping rate per minute
  - Cease generation moves once frequency is within "deadband" values

* Note: Sustained frequency < 59.90 Hz, or > 60.01 Hz, is an indication that a disturbance has occurred

Frequency Response

- Full Response (Red Zone): As frequency exceeds reasonable operational limits, all units capable of rapid response should move to balance load with generation
  - Triggered when frequency < 59.80 Hz or > 60.20 Hz
  - Observe frequency during Full Response operation and reduce the unit ramp rate once frequency reaches the Selective Response region

Frequency Response

- Emergency Response: As frequency continues to deteriorate, emergency measures will be required in accordance with actions developed in consultation with the BA, TOP, and RC
  - High Frequency
    - Take generation to its lowest stable output when frequency increases to 60.30 Hz
    - Start tripping units offline when frequency increases to 60.50
      - Smaller units with minimal impacts to transmission should be taken offline first
      - Plants with multiple units should trip generation offline
      - Subsequent generation may be taken off line as needed

Frequency Response

- Low Frequency
  - All hydro generation should be loaded when frequency declines to 59.70 Hz
  - All quick-start generation (combustion turbines) resources should be committed when frequency drops below 59.60 Hz
  - Underfrequency Load Shed-- relays start to operate automatically when frequency declines to 59.50 Hz
- Blackout Conditions
  - If conditions continue to deteriorate, generation should separate from the grid to protect equipment from damage at ~ 58.00 Hz
  - If the unit cannot self-support itself, the plant should shutdown in an organized manner in preparation for restart

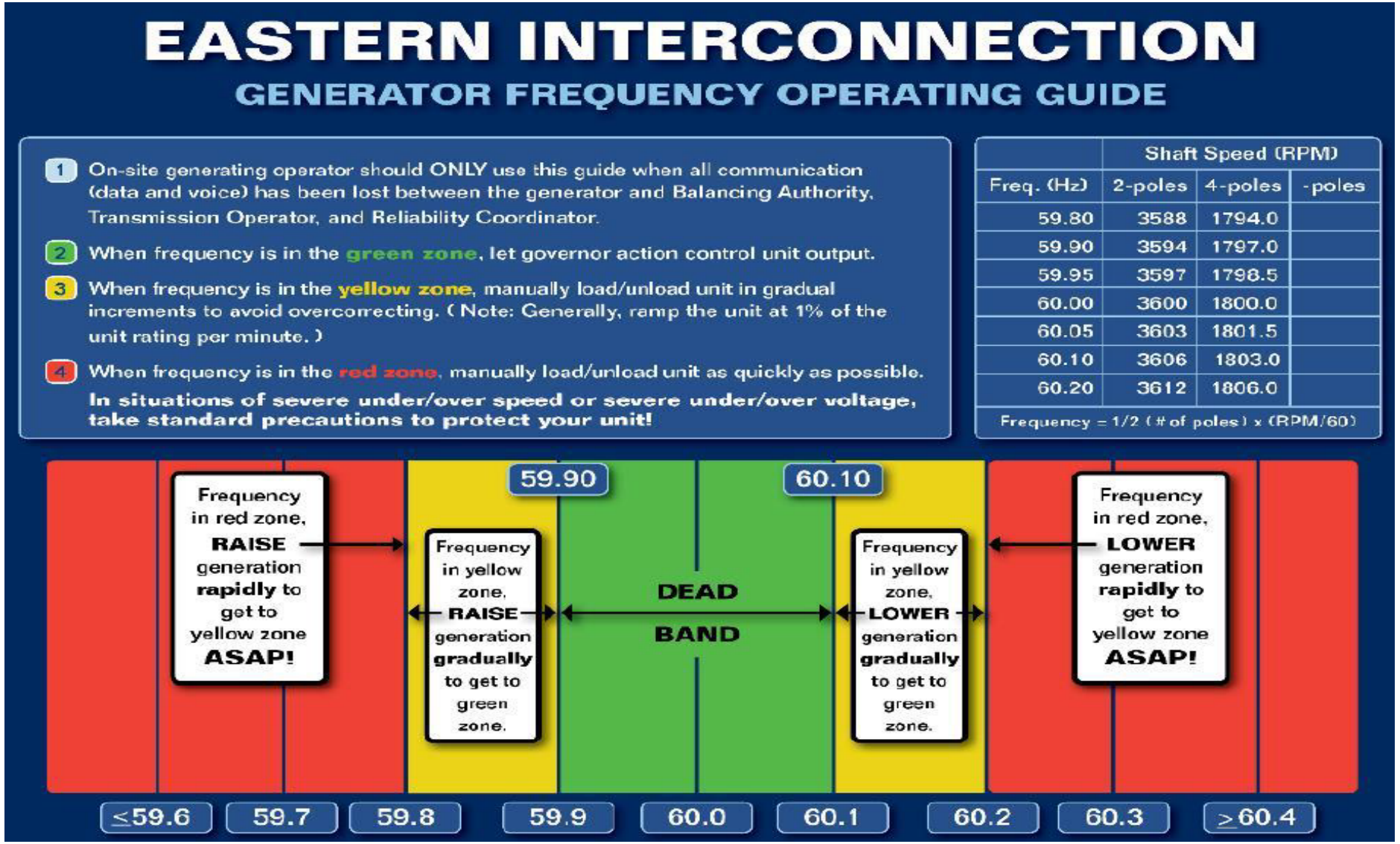
Frequency Response

- Green Zone—No control actions are necessary
  - 59.90Hz to 60.10Hz
- Yellow Zone – Selective response
  - 59.80Hz to 59.89 or 60.11 to 60.20Hz
  - Gradually maneuver generation to correct the frequency
  - Generation Ramp Rate = 1% of unit rating per minute
  - Sustained frequency in this range indicates a disturbance has occurred
  - Cease moving generation once frequency is within the Green Zone

Frequency Response

- Red Zone– Full Response
  - Frequency <59.80Hz or >60.20Hz
  - All units capable of responding should rapidly maneuver to balance load with generation
  - Reduce the Ramp rate of the units when frequency falls back into the Yellow zone
- Emergency Response
  - If the frequency continues to deteriorate, emergency measures will be required

Frequency Response



Questions?

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The Member Community is PJM's self-service portal for members to search for answers to their questions or to track and/or open cases with Client Management & Services