Unit Capability Testing
Objectives

- Identify the reactive capability testing process and requirements
Generator Reactive Testing

• PJM Generator Reactive Capability Testing
  – All individual units > 20 MVA and all aggregate units > 75 MVA which are connected to the BES must complete testing
    • This includes Wind and Solar units meeting the criteria
  – All units designated as Black-Start must complete testing
  – All Synchronous Condensers > 20 MVA which are connected to the BES must complete testing
  – Testing is required once every 5 years
    • No more than 66 months between consecutive tests
## Generator Reactive Testing

<table>
<thead>
<tr>
<th>Unit Type</th>
<th>MW Output</th>
<th>MVAR Output</th>
<th>Test Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil, Hydro &amp; Black Start</td>
<td>Maximum</td>
<td>Max Lag</td>
<td>One Hour</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>Max Lead</td>
<td>When limit reached</td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>Max Lag</td>
<td>When limit reached</td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>Max Lead</td>
<td>When limit reached</td>
</tr>
<tr>
<td>Synchronous Condenser or Generator that operates in Synchronous Condenser mode</td>
<td>N/A</td>
<td>Max Lag</td>
<td>One Hour</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Max Lead</td>
<td>When limit reached</td>
</tr>
<tr>
<td>Nuclear</td>
<td>Maximum</td>
<td>Max Lag</td>
<td>One Hour</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>Max Lead</td>
<td>When limit reached</td>
</tr>
<tr>
<td>Variable (i.e. – Wind &amp; Solar)</td>
<td>Variable</td>
<td>Max Lag</td>
<td>When limit reached</td>
</tr>
<tr>
<td></td>
<td>Variable</td>
<td>Max Lead</td>
<td>When limit reached</td>
</tr>
<tr>
<td><strong>Testing must done with at least 90% of turbines or inverters online</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Reactive Capability Testing – Scheduling the Test

• MOC (Unit Owner) Actions:
  – Submit an eDART no later than 3 business days prior to the test
    • Create a “MVAR Test” ticket
      ▪ Specify duration of test
      ▪ Any other relevant information
  – Transmission Owner(s) (TOs) and PJM Reliability Engineer (RE) will ensure the impacts of the testing are factored into the day-ahead studies
  – Shorter Notification times will be considered if PJM/TOs can ensure limits will not be violated
Reactive Capability Testing – Scheduling the Test

• Prior to scheduling the test, the MOC (Unit Owner) shall confirm with PJM RE that MW and MVAR data is being provided to PJM via ICCP
  – Identify/resolve any issues prior to scheduling the test

• Any scheduled (or unscheduled) maintenance on the unit must be completed, and all eDART tickets closed prior to scheduling the MVAR test
Reactive Capability Testing – Test Conditions

• The following are steps that will be considered and agreed upon prior to allowing the scheduled generator reactive capability testing;
  – Each scheduled test will be studied and approved on a case by case basis
  – All required mitigation steps will be agreed to and coordinated with all concerned parties,
    • PJM RE
    • The responsible MOC (Unit Owner)
    • The appropriate TOs
Reactive Capability Testing – Test Conditions

- PJM will NOT allow any violations of its normal operating criteria;
  - No equipment may be operated above:
    - Its normal rating on an actual basis
    - Its Emergency rating on a post-contingency basis
  - In the event of a facility rating discrepancy between PJM and the TO that cannot be resolved, PJM will default to the most conservative limit
Reactive Capability Testing – Test Conditions

• PJM will NOT allow scheduled generator reactive capability testing to place the system in an unacceptable state
  – However, equipment failure could result in unplanned situational constraints that would require immediate remedial action
  – Standard mitigation steps will be taken to return the facilities in violation back to normal limits within fifteen minutes
  – The mitigation steps taken may not cause limit violations on any other company’s equipment or facilities
  – PJM reserves the right to cancel the remainder of the testing
Reactive Capability Testing – The Day of the Test

- MOC (Unit Owner) will notify the PJM RE at least 3 hours before the start of the test to allow time for real-time studies to be completed.
- An additional 30-minute notification should be provided to PJM Transmission and TO Operators to allow adjustments to system voltages prior to the test.
  - TO Operators will coordinate any steps required to mitigate internal plant limitations with the Plant Operators or the MOC and PJM.
- If testing must be canceled or rescheduled, the MOC will inform PJM Reliability Engineer as soon as possible.
  - The MOC will coordinate the implementation of their portion of the exit strategy with PJM, if required.
Reactive Capability Testing – Mitigating Actions

• Adjustments may need to be made to local voltage schedules in order to accommodate the scheduled testing
  – Adjustments will be considered and studied on a case by case basis
  – The impact of these deviations will be monitored by the TO and PJM

• PJM will discuss the changes with the appropriate TO and if the recommendation does not cause a violation of a defined limitation, the TO should implement the PJM request
Reactive Capability Testing – Mitigating Actions

• PJM will retain control of other reactive facilities (capacitors, LTCs, etc.)

• If internal plant or TO limits restrict the request, PJM dispatch will study the limitations and recommend changes to plant facilities if appropriate
  – If the recommended changes cannot be implemented due to equipment or facility limitations, other options will be considered, including test cancellation or rescheduling
Reactive Capability Testing – What do the TOs do?

• Transmission Owner Actions:
  – The appropriate TOs will conduct studies in accordance with established company procedure in order to determine the effect of scheduled testing on their systems
  – The TOs will discuss, coordinate, and implement any actions necessary as required by mitigation strategies with PJM prior to the start of testing
  – The TO will communicate MVAR output step changes to the testing unit in coordination with PJM. In general, MVAR step changes should be no greater than 100 MVAR increments
**Reactive Capability Testing – What does PJM do?**

- **PJM Actions:**
  - PJM RE and Power Directors will run job studies to ensure that there is no conflict between the testing and any planned transmission outage
    - PJM will suggestion a more appropriate date for the test, if necessary
  - Once the PJM Reliability Engineer is contacted by the MOC, they will contact the TOs of all regions concerned in order to initiate the transmission operator’s study process
  - PJM Reliability Engineer will ensure that PJM dispatch is aware of scheduled reactive capability tests and communicate the pre-studied mitigating action plan via the PJM Transmission Log
Reactive Capability Testing – What does PJM do?

- PJM RE and/or Dispatch will discuss possible mitigation strategies with the appropriate TOs
  - PJM RE will contact the MOC no later than two hours prior to scheduled testing to inform them whether mitigation steps will be required
  - PJM RE will coordinate with the appropriate MOCs and TOs in order to implement any required mitigation strategy
- PJM will verify the expected unit output levels with the TOs and ensure that the AVR is in service
- PJM Reliability Engineer will coordinate with the TO in making MVAR output step changes with the testing unit
Reactive Capability Testing – What does PJM do?

- If the testing must be cancelled or rescheduled, PJM RE will contact the MOC and TOs as soon as possible
- PJM RE will coordinate the implementation of the exit strategy with the MOC and TOs, if required
- PJM RE will coordinate all actions and communications between the MOC and TOs
Reactive Capability Testing – What if I need to Cancel?

• Test Cancellation
  – PJM dispatch and/or the impacted parties may cancel the generator reactive capability testing for the following reasons:
    • Internal planning issues
    • Emergency procedures
    • Inability to control actual or post-contingency voltage issues created by scheduled testing
    • Any operating issues created on TO equipment not monitored by PJM
  – Cancellation of the generator reactive capability test will be communicated to all impacted parties
Reactive Capability Testing – What if I need to Cancel?

- PJM will document all cancellations and terminations including the party responsible and the reason for the cancellation or termination.
Reporting Test Results
Reactive Capability Tests – Testing Criteria

- Units should be tested against their expected capability
  - For new units, Vendor “D” curves and exciter limiter settings should be used
  - For existing units, previous test results would be an expected minimum

- Testing should respect the normal voltage limits at the system bus
  - The TO/PJM may need to make system adjustments to ensure this
  - Voltage schedules may be exceeded during the testing
Reactive Capability Tests – Testing Criteria

• Results should be based on capability *actually achieved* during the operating conditions
  – For some Black Start Unit testing, some calculations can be used
    • These should be the exception
    • Not used on an ongoing basis

• If the generator uses hydrogen cooling, the hydrogen pressure should be set where it normally operates
Reactive Capability Tests – Reporting Data

• Over-excited (Lagging) test results are the values of MVAR output that can be sustained for an hour

• Under-excited (Leading) test results are the MVAR values seen once any unit limit is reached

• For each testing point, record the unit MW and MVAR values for the following:
  • Generator Terminals (low side)
  • Station Auxiliaries
  • Generator Step-up Transformer (low side net)
  • Generator Step-up Transformer (high side net)
Reactive Capability Tests – Reporting Data

• Report scheduled and actual voltages at the system bus and the unit terminals

• Report nameplate data for the unit step-up transformer
  – Impedance
  – MVA rating
  – High and low side voltages
  – Available tap settings
  – Existing tap setting used during the test
Reactive Capability Tests – Reporting Data

• The reason for any limitations noted during the testing should also be noted
  – Aux bus voltage limits
  – Generator vibration
  – Generator temperatures
  – Hydrogen pressure limits
Reactive Capability Testing – The Day of the Test

• Generator Owner shall complete Reactive Capability Testing Form with test results

• The form should be completed electronically within 30 calendar days from the test date

http://www.pjm.com/~media/documents/manuals/manual-links/m14d/reactive-testing-schedule-form-version-0.ashx
Reactive Capability Testing – The Day of the Test
Reactive Capability Testing – Reporting Data

• If portions of the test are completed on separate days (e.g. tests at Econ Min completed on day 1 and tests at Econ Max 90 days later) all test data shall be submitted within 30 days after each portion of the test.
  – Also, updates to eDART D curves shall be made if required.
    This ensures PJM has most accurate and timely data

• If portions of the test are completed on separate days, use the earliest of those dates as the test/verification date for record and periodicity purposes
Reactive Capability Testing – Reporting Data

• All portions of reactive testing on a facility shall be completed within six calendar months after the initial test, otherwise PJM will consider the test unsuccessful and retesting will be required
  – Provides flexibility in test scheduling
  – Meets desire for tests to be completed under somewhat similar seasonal conditions
  – Meets desire for tests to be completed prior to potential significant changes in unit physical or operational characteristics
  – Meets desire to put in place a finite date to fully complete test requirements
Reactive Capability Testing – Reporting Data

• Beginning in 2015, the GO (or TO) shall submit to PJM annually by January 31st:
  – A listing of the units successfully tested within the prior five years (including test date)
  – A non-binding test schedule for the current year and the next subsequent four years which includes the applicable unit to be tested and the year the test is proposed to be completed
  – PJM to include test schedule form in manual revisions
• PJM will provide feedback on a periodic basis to generation owners on the status of their reactive capability test results
  – PJM will also provide the results of generation reactive capability tests to the appropriate TO

• PJM will analyze the reactive capability test results in the same calendar year in which the reactive capability test was performed for the unit

• PJM Staff will conduct periodic audits of generator reactive capability test results and will provide summary report information to the PJM System Operations Subcommittee and the PJM Operations Committee on a periodic basis
Reactive Capability Testing – Analyzing Results

• Units Testing Within 5% of Stated Limits
  – The Unit or wind station will be considered as having fully demonstrated their stated reactive capability
  – PJM will notify the MOC/GO that their unit(s) achieved their reactive capability, and no further action will be required
Reactive Capability Testing – Analyzing Results

- **Units Testing Below 5% of Stated Limits**
  - Units or wind stations with test results under 5% of their stated limits will be considered as not meeting their stated reactive capability
  - PJM will determine if either internal or external operational limitations contributed to the failure to meet the stated capability, based on reasons documented within the submitted test results
  - There is no penalty for not meeting the stated capability, but PJM must investigate to ensure that realistic values for that unit are entered and used going forward
If a unit that claimed *external* operational limitations;

- PJM will attempt to confirm the external limitations and identify possible remedial measures in helping the unit meet started levels in future tests

- If an external limitation is confirmed, PJM will provide confirmation to the MOC/GO that their unit performed below its stated reactive capability due to external limitations and will not require any further action

  - The assumption is that the limiting condition is temporary and the unit could perform as stated
Reactive Capability Testing – Deviation follow-up

• If PJM could not confirm the external limitation, the MOC/GO will be required to either;
  – Permanently reduce the reactive capability modeled within the PJM EMS by entering a “New Default” eDART MVAR ticket
  
  OR

  – Retest to demonstrates the stated capability of the unit.
  • If the MOC chooses to retest the unit, PJM will require that a temporary eDART MVAR ticket be submitted that will remain active until the unit demonstrates the original stated capability
Reactive Capability Testing – Analyzing Results

• For units that claimed *internal* operational limitations,
  – PJM will notify the MOC/GO that their unit performed below its stated reactive capability
  – *IF* the internal limitation was caused by an external condition which the TO and PJM could not correct during the testing (i.e. - high or low transmission system voltages)

  **AND**
  • The Plant/MOC/GO notified the TO of the condition during the testing
  • PJM confirms the external condition caused the internal limitation

  – The unit will be considered as meeting its stated capabilities, and PJM will require no additional action
Reactive Capability Testing – Analyzing Results

• **IF** the internal limitation was caused by an external condition which the TO and PJM could not correct during the testing (i.e. - high or low transmission system voltages) **but** the Plant/MOC/GO did **not** notify the TO of the condition during the testing;
  - PJM will require the MOC/GO to either;
    • Permanently reduce the reactive capability modeled within the PJM EMS by entering a “New Default” eDART MVAR ticket  
      **OR**
    • Retest to demonstrates the stated capability of the unit.
      - If the MOC chooses to retest the unit, PJM will require that a temporary eDART MVAR ticket be submitted that will remain active until the unit demonstrates the original stated capability
PJM’s Net Capability Test Process
Net Capability

• Net Capability is the net number of MW available from a unit or station after any station service power is subtracted from the total MW generated under various conditions.

• The Net Capability test is proof that the unit can perform to this capability.

• The duration of verification tests or operational data shall be a 2-hour average for nuclear, fossil steam and combined-cycle units, a 1-hour for hydro, pumped storage, simple cycle combustion turbine, and diesel units.
Determining Unit Capability

- The Net Capability of a combined-cycle unit is determined by operating both the CT and steam components of the unit simultaneously. The output of all of the components can be netted to determine the CC Net Capability.

- The Net Capability of a steam unit is determined by using any normal procedures for increasing the unit output:
  - Turbine over-pressure
  - Boiler over-rating
  - Cycle modification
  - Other normal operating procedures
Determining Unit Capability

• The Net Capability of a CT is the maximum amount of MW’s that the unit can produce

• The Net Capability for a hydro/pumped storage storage unit is how much energy can be produced at the probable time of the PJM peak while considering any operating restrictions and reservoir storage

• The Net Capability for a nuclear unit is determined by considering its nuclear fuel management program and any regulatory restrictions
Wind Resources

• For Wind Resources (and other intermittent capacity resources), please see
Planned Resources

• The Net Capability of a planned resource:
  – Steam or CC
    • Based on manufacturer’s specifications
  – CT or CC
    • Based on elevation of the unit location, available fuel type, owner system policy with respect to maximum output
  – Hydro
    • Based on owner system’s estimate of head
Net Capability Verification

- Net Capability is based on current operating performance or test results
- Summer and Winter Net Capability values confirmed annually
  - If adequate data is available from normal operation, no test is required
- If a known change occurs in the Net Capability of a unit or is indicated by operating data or test results, the change will become effective as soon as possible
  - The Resource Adequacy Planning Department of the PJM RTO is responsible for the establishment of test procedures required to confirm such values including any amount which could be treated as limited energy capability
Reductions in Net Capability

• There is no need to reduce the net capability of a unit for unplanned deratings or temporary capacity restrictions if the capability will be restored.

• If the capability cannot be restored by the end of the next Delivery Year, a reduced Net Capability Value may be requested by the owner.
  – These changes should be made via the Capacity Modification (CAPMOD) process of the PJM Capacity Market.
Unlimited/Limited Energy Capability

- Unlimited energy capability
  - Any part of a unit’s capability that can be sustained for 10 hours

- Limited energy capability
  - Any part of a unit’s capability that cannot be sustained for at least 10 hours
  - Only limited for the periods where it does not meet that criteria
Seasonal Capability Value Verification

- Each generation owner is responsible for the determination and reporting of summer and winter Net Capability values
  - The summer verification window is the first day of June through the last day of August
  - The winter verification window is the first day of December through the last day of February
  - Data that is used to satisfy the summer net capability test may be used to satisfy winter test requirements after adjustment to the appropriate ambient winter conditions
  - Data from normal operations during these periods can be used to satisfy the seasonal verification test
  - Reporting is accomplished through the PJM eGADS reporting system
  - The deadlines for seasonal verification test result submittal are September 30 for the June-July-August summer test period and March 31 for the December-January-February winter test period*

*a data submission charge of $500/day can be applied to any data not submitted in accordance with published deadlines
Data to be Reported

• Event Data
  – Each time a unit experiences a change in operating status or capability, an event is recorded
  – From these event reports a unit’s operational history can be reconstructed

• Generation Performance Data
  – A unit’s actual generation data for the month must be reported

• Fuel Performance Data
  – A unit’s actual fuel consumption data for the month must be reported

• Net Capacity Verification Test Data
  – Results from the summer or winter verification tests
Seasonal Capability Verification

• The duration of verification tests or operational data shall be two a 2-hour average for nuclear, fossil steam and combined-cycle units, one a 1-hour for hydro, pumped storage, simple cycle combustion turbine, and diesel units
Reduced Capability

- The Net Capability reported for a unit following its date of commercial operation shall in no case exceed an amount determined by the owner but for PJM accounting purposes may initially be less than that amount.

- The extent of any such reduction in reported capability may be determined by the company in such manner as will permit the most effective use of its own resources.
Appendix
Summer/Winter Conditions

- The Summer/Winter Net Capability of each unit or station is based on summer/winter conditions and on the power factor level normally expected for that unit or station at the time of the PJM summer/winter peak load.

- Summer/Winter conditions reflect the 50% probability of occurrence (approximated by the mean) of ambient site conditions at the time of the PJM summer/winter peak load. Conditions are based on plant records or local weather bureau records of the past 15 years, updated at 5 year intervals. When local weather records are not available, the values are estimated from the best data available.

- For fossil and nuclear steam units, summer/winter conditions mean the probable condenser intake water temperature at the time of the PJM summer/winter peak load. Conditions include the expected temperature of once-through or open cooling systems as well as the performance of cooling towers under expected ambient conditions.
Summer/Winter Conditions (cont.)

- For combustion turbine units, summer/winter conditions mean the probable ambient air temperature and humidity condition at the unit location at the time of the annual summer/winter PJM peak.
- The determination of the Summer Net Capability of hydro and pumped storage units is based on operational data or test results taken once each PJM delivery year during the Summer verification window.
- The determination of the Winter Net Capability is waived for hydro and pumped storage units.
- For combined-cycle units, summer/winter conditions mean the probable intake water temperature of once-through or open cooling systems and/or the performance of cooling towers and combustion turbines under expected ambient conditions at the unit location at the time of the annual summer/winter PJM peak.
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
Resources and References

