Attachment E: PJM Generator and Synchronous Condenser Reactive Capability Testing

E.1 Objective

The objective of reactive capability testing for generators is to improve the transmission system reliability by accurately determining generator and synchronous condenser reactive capability on a regular basis. Also, this testing could identify any conditions which are limiting the reactive capability of generating units in PJM. PJM encourages testing to be coordinated between PJM, the Generator testing facility Owner, and the local Transmission Owner's Local Control Center (LCC) to ensure that the impact on system operations is minimized. Testing is intended to demonstrate reactive capability for those conditions where reactive reserves or voltage control would be required.

PJM will evaluate the Generator Reactive Capability Testing requirements contained within this document and may expand testing to various MW output levels if experience indicates it is beneficial to do so. It is the intent of these procedures to align with NERC Reliability Standard MOD-025-2 so separate tests to meet the NERC requirements and the PJM requirements are not needed. However, certain differences will remain between M14D, Attachment E and MOD-025-2 to provide continuity with PJM requirements and to provide data for real-time operational needs.

E.2 General Requirements

Note that the term “facilities” throughout this Attachment E includes individual generating units, aggregated generating plants including wind farms and solar projects, and synchronous condensers. The requirements in this attachment apply to all applicable facilities within the PJM RTO footprint. The requirements do not apply to PJM capacity resources that are located outside the PJM RTO footprint or to energy storage installations such as batteries or flywheels.

The following facilities are required to perform reactive capability testing:

1. Individual generating units with a gross nameplate rating greater than 20 MVA and directly connected to the Bulk Electric System
2. Generating plants/facilities with a gross aggregate nameplate rating greater than 75 MVA including variable resources such as wind, solar, run of river hydro, etc. nominal capacity greater than 70 MW, wind generating stations connected at a common bus with an aggregate rating greater than 70 MW, and all black start units are required to perform a reactive capability test.
3. Synchronous condensers with a gross nameplate rating greater than 20 MVA and directly connected to the Bulk Electric System
4. All generating units providing PJM Black Start Service
5. All other individual units/facilities with nominal capacity less than 70 MW and non-black start units will verify the reactive capability reported in the PJM e-DART system on a periodic basis consistent with PJM Manual 14D.
3. **Generation Owners and Transmission Owners of synchronous condensers** are required to test approximately 20% of their applicable facilities number of their eligible assets annually, totaling 100% of their eligible applicable facilities assets over an 5-year period. More frequent testing may be done if the Generator Owner so chooses.

- The MOC for the operating company of a joint owned generating facility is responsible for scheduling the tests and updating the applicable eDART D curves as required.

4. **For the maximum lagging test at maximum real power output for generators and the maximum lagging test for synchronous condensers, The PJM generator reactive capability testing period will begin on May 1 and continue through September 30 during on peak hours (0700 – 2300 hrs. EPT). This testing cycle will repeat on an annual basis, ensuring that all designated units are tested at least once in a five year cycle.**

5. Generator reactive capability testing will take place Monday thru Friday, between 0900 and 1100 hours, Eastern Time.

6. **For all other required reactive testing, The Generator Owner will determine the best time to conduct these tests. This test Testing may be conducted in conjunction with other testing (including the Net Demonstrated Capability real power testing), provided all other requirements of this test the reactive capability tests are met. Facilities should All equipment will be tested with all auxiliary equipment needed for normal operation in service.**

7. As an alternative, data collected during routine operation of the unit facility is acceptable, provided all test requirements are met.

8. The tests required are functional and do not require special instrumentation. They are designed to demonstrate that the ratings can be obtained for the time periods required under normal operating conditions for the equipment being tested.

9. Projected system conditions must permit the unit/facility to operate at the required real power and reactive power output full capacity (or at least 50% of nameplate capacity for wind generating stations) without adversely impacting system operations.

10. **PJM will consider other test periods on a case by case basis, so long as proposed testing periods do not adversely impact system operations.**

### E.3 Testing Requirements

- **Testing Requirements for Non-Wind Units Greater than 70 MW and Black Start Units**

  - For all applicable generating facilities except variable resources such as wind and solar, maximum over-excited (lagging) and maximum under-excited (leading) reactive capability tests outputs (MVAR) is required to be tested at the maximum real power output the facility is expected to operate (e.g. Economic Maximum) are required or above demonstrated capability (i.e. a single MW point test). The maximum lagging reactive capability test should be conducted for a minimum of one hour. Data for the maximum leading reactive capability test may be recorded as soon as a limit is encountered.

  - For variable resources such as wind and solar, maximum over-excited (lagging) and maximum under-excited (leading) reactive capability tests are required. At least 90% of
the wind turbines or photovoltaic inverters at a site must be on-line during the tests. Data for these tests may be recorded as soon as a limit is encountered.

- For all applicable generating facilities except nuclear powered generating units and variable resources such as wind and solar, maximum over-excited and maximum under-excited reactive capability tests at the minimum real power output the facility is expected to operate (e.g. Economic Minimum) are required. Data for these tests at minimum real power output may be recorded as soon as a limit is encountered.

- Applicable hydroelectric generating facilities (e.g. run of river, pumped storage) shall perform maximum leading and maximum lagging tests at maximum real power output and at minimum real power output. The maximum lagging reactive capability test at maximum real power output should be conducted for a minimum of one hour. Data for maximum leading at maximum real power output and for tests at minimum real power output may be recorded as soon as a limit is encountered.

### Testing Requirements Summary

<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, HYDROELECTRIC &amp; BLACKSTART</td>
<td>MAX</td>
<td>MAX LAG</td>
<td>ONE HOUR</td>
</tr>
<tr>
<td></td>
<td>MAX</td>
<td>MAX LEAD</td>
<td>WHEN LIMIT REACHED</td>
</tr>
<tr>
<td></td>
<td>MIN</td>
<td>MAX LAG</td>
<td>WHEN LIMIT REACHED</td>
</tr>
<tr>
<td></td>
<td>MIN</td>
<td>MAX LEAD</td>
<td>WHEN LIMIT REACHED</td>
</tr>
<tr>
<td>SYNCHRONOUS CONDENSER</td>
<td>-</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>MAX</td>
<td>MAX LAG</td>
<td>ONE HOUR</td>
</tr>
<tr>
<td></td>
<td>MAX</td>
<td>MAX LEAD</td>
<td>WHEN LIMIT REACHED</td>
</tr>
<tr>
<td>VARIABLE (E.G. WIND AND SOLAR) (Testing done with at least 90% of turbines or inverters on line)</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>
</tbody>
</table>
For generating units of 20 MVA or less that are part of a plant greater than 75 MVA in aggregate, record data either on an individual unit basis or as a group. Units providing PJM Black Start Service shall provide test data on an individual unit basis.

- A steady active and reactive real power output shall be maintained during the test.
- For synchronous condensers the over-excited reactive capability test should be conducted for a minimum of one hour. Data for the under-excited reactive capability test may be recorded as soon as a limit is encountered.

Generation or synchronous condenser stations that have multiple facilities that require testing shall perform tests on only one facility at a time. The remaining operating facilities at the station shall operate normally.

**Exception Criteria:** Lagging/Leading tests are required depending on unit type. All exceptions must be documented and reviewed by PJM and Transmission Owners. Test requirements are as follows:

<table>
<thead>
<tr>
<th>Unit Type</th>
<th>Required Testing</th>
<th>Exception Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear</td>
<td>Lagging Test</td>
<td>Documented Exception to Lagging based on impact to System Reliability</td>
</tr>
<tr>
<td></td>
<td>Minimum MVAR Test</td>
<td></td>
</tr>
<tr>
<td>Black Start and units with hot start time of 8 hours or less</td>
<td>Lagging Test</td>
<td>Not Applicable</td>
</tr>
<tr>
<td></td>
<td>Leading Test</td>
<td></td>
</tr>
<tr>
<td>All Other</td>
<td>Lagging Test</td>
<td>Documented Exception to Lagging test based on impact to System Reliability</td>
</tr>
<tr>
<td></td>
<td>0 MVAR Test</td>
<td></td>
</tr>
</tbody>
</table>

Note 1: Nuclear Units shall perform a Minimum MVAR Test as noted above, attempting to achieve minimum stated D Curve limit.

The reactive capability curve and minimum excitation limiter settings for each unit will be used to determine the expected reactive capability. If a unit has been tested previously,
the expected reactive capability for a new test should reflect at a minimum the reactive
capability that was previously demonstrated.

45. **Units Facilities** are to be tested while maintaining the voltage within normal
operating limits on the system bus (pre- and post-contingency voltage limits). This
requirement may require a departure from scheduled voltage during the test, provided
there will be no adverse effects on the validity of test results can be
demonstrated electrical system. The Generator Owner will need to
cordinate between its facility owner, the designated LCC, PJM, and other unit facilities in the area will be required in order to allow the unit facility being
tested to demonstrate its maximum reactive capability while maintaining system voltages
within acceptable limits.

46. All reasonable measures shall be taken to ensure the results from the reactive
capability test are based upon actual operating conditions. If it is not possible to maintain
the system voltage within operating limits, for non-black start unit leading capability tests,
then it is acceptable to calculate the non-black start unit leading reactive capability
quantities. Calculated test results will not be acceptable on an ongoing basis. Black
start units and units with hot start time of 8 hours or less are required to test both
leading and lagging reactive capability.

47. For hydrogen-cooled generators and synchronous condensers, the hydrogen
pressure should be raised to the normal operating pressure. If the facility cannot be
operated at its normal hydrogen pressure the test shall be postponed until this condition
is corrected. Hydrogen pressure cannot be raised, then the reason for this condition
should be documented and the appropriate reactive capability curve should be used.

48. The over excited reactive capability test should be conducted for a minimum of one
hour. Data for the under-excited reactive capability test may be recorded as soon as a
limit is encountered.

49. When the maximum sustained over-excited and under-excited reactive output
during the test is achieved, the MW and MVAR outputs at the generator/synchronous
condenser terminals (low side gross), auxiliaries, the generator/synchronous condenser
step-up transformer (GSU) primary (low side net, after auxiliaries), and the GSU
secondary (high side net) should be recorded. All other applicable data on the reporting
forms shall also be recorded.

- If metering is unavailable, it may be necessary to calculate some of these quantities. A
  note should be provided in the “Remarks” section of the data reporting forms for points which are calculated.

- Link to Reactive Capability Testing Form: [XXXXXX]

- PJM will evaluate the reported values as compared to the average default eDART “D”
curve values and contact the owner as required to validate the data. The test data
values consistent with requirements. The average values will normally serve as the basis
for modifying the default reactive curves within eDart.

- During the test, the scheduled and actual voltages at the system bus and the
generator/synchronous condenser terminals should also be recorded. In addition, the
nameplate GSU/Synchronous Condenser SU transformer impedance, MVA rating,
primary and secondary voltage ratings and available tap settings, and the existing GSU
tap setting should be provided.
21. The reasons for any limit to unit reactive capability during the test should also be specified (for example, reactive capability curve limit, minimum excitation limiter settings, field current limitation, generator/synchronous condenser voltage, auxiliary bus voltage, system voltage limits, generator/synchronous condenser vibration, generator/synchronous condenser temperatures, hydrogen pressure restriction, shorted rotor turns, etc.) in the remarks section.

For Wind Generating Stations with an Aggregate Nameplate Rating Greater than 70 MW

1. Only wind units of Type 3 (doubly-fed asynchronous) and Type 4 (full converter interface) will be tested for reactive capability, exclusive of static reactive power compensation devices.

1. The over-excited (lagging) and under-excited (leading) reactive capability outputs (MVAR) is required to be tested at 50% or greater of aggregate wind generating station nameplate rating (i.e. a single MW point test).

2. The active and reactive power output shall be maintained as steady as possible during the test.

3. The reactive capability curve and minimum excitation limiter settings for each wind generating station will be used to determine the expected reactive capability. If a wind generating station has been tested previously, the expected reactive capability for a new test should reflect at a minimum the previous reactive capability that was demonstrated.

4. Wind generating stations are to be tested while maintaining the voltage within normal operating limits on the system bus (pre- and post-contingency voltage limits). This requirement may require a departure from scheduled voltage during the test, provided no adverse effect on the validity of test results can be demonstrated. The Generator Owner will need to coordinate between its designated LCC, PJM, and other units in order to allow the unit being tested to demonstrate its maximum reactive capability while maintaining system voltages within acceptable limits.

5. All reasonable measures shall be taken to ensure the results from the reactive capability test are based upon actual operating conditions. If it is not possible to maintain the system voltage within operating limits, for wind generating stations leading capability tests, then it is acceptable to calculate the wind generating station leading reactive capability quantities. Calculated test results will not be acceptable on an on-going basis.

6. When the maximum sustained over-excited and under-excited reactive output during the test is achieved, the MW and MVAR outputs at the aggregated collector bus low side terminals (low side gross), auxiliaries, the generator step-up transformer (GSU) primary (low side net, after auxiliaries), and the GSU secondary (high side net) should be recorded.

If metering is unavailable, it may be necessary to calculate some of these quantities. A note should be provided in the “Remarks” section of “Lagging and Leading/Zero Form R” for points which are calculated.

For wind generating stations on Lagging Form R, record only the instantaneous value in the “Start of Test” row and Stated Capability (previous tested value if applicable). The 15 min, 30 min, 45 min, and End of Test rows are not applicable.

PJM will evaluate the reported values as compared to the average values consistent with requirements. The average values will serve as the basis for modifying the default reactive curves within eDart.
7. During the test, the scheduled and actual voltages at the system bus and the aggregated collector bus low side terminals should also be recorded. In addition, the nameplate GSU impedance, MVA rating, primary and secondary voltage ratings and available tap settings, and the existing GSU tap setting should be provided.

8. The reasons for any limit to wind generating station reactive capability during the test should also be specified (for example, reactive capability curve limit, minimum excitation limiter settings, field current limitation, generator voltage, auxiliary bus voltage, system voltage limits, generator vibration, generator temperatures, shorted rotor turns, etc.) in the remarks section.

**E.4 Notification and Reporting Requirements**

If non-cost operations (the adjustment of generator MVAR output or the movement of PAR or LTC transformer taps) or off-cost operations are required to accommodate the test, PJM will communicate these requests directly to the appropriate LCCs and MOCs.

**E.4.1 MOC (or LCC if testing a synchronous condenser) Actions:**

Proposed testing dates/times should be communicated via eDARTart to the PJM Dispatch, PJM Reliability Engineer and the LCC no later than noon 3 business days prior to the test, ensuring testing impacts are incorporated into day-ahead studies. PJM and LCCs will consider shorter notification times and try to accommodate reactive testing while ensuring that operating limits are not violated.

The test notification shall be submitted using a “MVAR Test” Ticket in which should include the test duration, should be provided, notes in the Description field on the type of test or tests that are planned to be performed, as well as any additional relevant information for the test within the description field.

Prior to the test scheduling, the MOC (Generation Owner) or LCC (Synchronous Condenser Owner) shall confirm with the PJM Reliability Engineer that accurate telemetered MW and MVAR data is being provided to PJM via ICCP. If issues are identified, they are required to be resolved before proceeding with the testing scheduling of the unit/facility.

Any scheduled or unscheduled maintenance work on the unit/facility scheduled for testing must be complete and all eDART tickets cleared prior to contacting PJM for the purpose of initiating the study process.

- The MOC (or LCC for synchronous condenser testing) will contact PJM Reliability Engineer at least three hours prior to the start of the scheduled testing in order to initiate the real-time study process.

Real-time testing should be coordinated with the LCC and PJM Transmission-Power Dispatchers. At least 30 minutes notice should be provided to allow PJM and the LCC operators to adjust the system to ensure testing does not result in voltage limit violations.

- The LCC will coordinate any required transmission mitigation steps to resolve internal generating plant limitations as reported by the plant or the MOC with PJM Reliability Engineer.
If during the test a unit is unable to achieve its stated capability due to external operational limitations or internal operational limitations caused by an external condition, such as high or low transmission system voltage, the plant or the MOC must communicate this issue to the LCC and the PJM Reliability Engineer prior to completing the test. The LCC and PJM will work together to adjust the transmission system voltage and mitigate the external condition. If the actions of the LCC and PJM cannot mitigate the external operational limitations or internal operational limitations caused by an external condition the PJM Reliability Engineer will provide confirmation to the MOC that their unit(s) did not meet the stated reactive capability due to an external limitation, and no further actions will be required of the MOC for said unit(s). The PJM Reliability Engineer will document that the unit could not achieve its stated capability due to an external limitation and will log the external limitation on the applicable eDART reactive test ticket.

If testing must be canceled or rescheduled, the MOC (or LCC for synchronous condenser testing) will inform the PJM Reliability Engineer as soon as possible. The MOC (or LCC for synchronous condenser testing) will coordinate the implementation of their portion of the exit strategy with PJM, if required.

GeneratorFacility owner shall submit complete PJM Leading and/or Lagging Reactive Capability Testing Forms to reactivetesting@pjm.com within 30 calendar days after completion of the testing. If portions of the test are completed on separate days (e.g. tests at minimum output completed on day 1 and tests at maximum output completed 90 days later) all test data shall be submitted within 30 days after each portion of the test, and eDART D curves updated appropriately. 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 invalid. Separate notifications are required if portions of the testing are planned to be done on separate days.

The MOC will coordinate all actions with PJM dispatch.

LCC Actions:

- The appropriate LCCs will conduct studies in accordance with established company procedure in order to determine the effect of scheduled testing on their systems.
- The LCC should contact the PJM Reliability Engineer with any possible concerns regarding the scheduled testing.
- The LCC support staff will ensure that the LCC operators are aware of scheduled reactive capability tests and communicate the pre-studied mitigating action plan.
- Prior to studying the test, the LCC will verify, with the PJM Reliability Engineer and the generating station or synchronous condenser station, the expected MW and MVAR output levels of the unit during testing, and ensure that the AVR is in service.
- The LCC will contact the PJM Reliability Engineer no later than two hours and 15 minutes prior to the scheduled test start time in order to discuss the results of their studies and the mitigating steps required, if any.
- The LCC will discuss, coordinate, and implement any actions necessary as required by mitigation strategies with PJM prior to the start of testing.
The LCC 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.

If testing must be canceled or rescheduled, the LCC will inform PJM Reliability Engineer as soon as possible.

The LCC will coordinate the implementation of their portion of the exit strategy with PJM, if required.

The LCC will coordinate all actions through the PJM Reliability Engineer or Power Dispatcher.

**E.4.3 PJM Actions:**

- All testing requests will be reviewed by the PJM Reliability Engineers and Power Directors Dispatchers to ensure that there is no conflict between the testing and any planned transmission outage. PJM will give the MOC (or LCC for synchronous condenser testing) a suggestion for a more appropriate date and time to conduct the test, if necessary.

- The PJM Reliability Engineer shall verify the accuracy of the telemetry data with the generation owners prior to commencing the test. If issues are identified, they are required to be resolved before proceeding with the test scheduling of the unit.

- If the testing must be cancelled or rescheduled, PJM Reliability Engineer will contact the MOC and LCCs as soon as possible.

- The PJM Reliability Engineer will coordinate the implementation of the exit strategy with the MOC and LCCs, if required.
The PJM Reliability Engineer will coordinate all actions and communications between the MOC and LCCs.

### E.5 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 LCC equipment not monitored by PJM.

Cancellation of the generator reactive capability test will be communicated to all impacted parties.

PJM will document all cancellations and terminations including the party responsible and the reason for the cancellation or termination.

### E.6 Voltage Schedules

Adjustments may need to be made to local voltage schedules in order to accommodate the scheduled testing. These adjustments will be considered and studied on a case by case basis.

To obtain better test results, units at the same location of the testing unit may elect to operate at the upper or lower end of their assigned voltage schedule’s bandwidth.

Operating beyond the assigned voltage schedule may be acceptable based on PJM’s real-time and contingency analysis. All parties must be informed and in agreement prior to this occurring.

#### Note

Deviate from voltage schedule to demonstrate reactive capability while monitoring impacts to limits using SA packages.

PJM will discuss the changes with the appropriate LCC and if the recommendation does not cause a violation of a defined limitation, the LCC should implement the PJM request.

PJM will retain its control of the reactive facilities, such as transmission capacitors, LTCs, and generator MVAR output.

If internal plant or LCC 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.

### E.7

#### Exit Strategy

#### E.7.1 Risk
E.7.2 Requirements

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, to include PJM Reliability Engineer, the responsible MOC, and the appropriate LCCs, prior to the scheduled testing.

E.7.3 Parameters

PJM will NOT allow operation over any applicable post-contingency STE or LTE emergency ratings.

PJM will NOT allow operation over any applicable pre-contingency normal rating.

In the event of a facility rating discrepancy between PJM and the LCC that cannot be resolved, PJM will default to the most conservative limit.

In the event that the testing results in an unexpected thermal or voltage violation, standard mitigation steps will be taken to return the facilities in violation back to normal limits within fifteen applicable timeframes minutes.

The mitigation steps taken will not cause limit violations on any other company's equipment or facilities.

E.8 Post-Test Evaluation

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 LCC operator.

PJM will typically analyze the reactive capability test results within 60 days of receipt of the test data and provide feedback to facility owners on the status of their reactive capability test results. PJM will also provide the results of generation reactive capability tests to the appropriate LCC operator, in the same calendar year in which the reactive capability test was performed for the unit.

PJM 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.

Test Evaluation

PJM will evaluate each unit's facility's reactive capability test results against its stated reactive capability limits modeled within eDART and the PJM EMS. This evaluation will determine which units performed over, under, or within 5% of their stated limits for the maximum lagging test at maximum real power output and the maximum leading test at minimum real power output, as well as what follow-up steps are necessary to ensure that the correct information is modeled within eDART and the PJM EMS.
**E.8.2 Units Facilities Testing Within 5% of Stated Limits**
Units or wind generating stations with test results within 5% of their stated limits for the maximum lagging test at maximum real power output and the maximum leading test at minimum real power output will be considered as having fully demonstrated their stated reactive capability.
PJM will notify the MOC or LCC for synchronous condensers that their units achieved their reactive capability, and no further action will be required.

**E.8.3 Units Facilities Testing Over 5% of Stated Limits**
Units or wind generating stations with test results over 5% of their stated limits for the maximum lagging test at maximum real power output and the maximum leading test at minimum real power output will be considered as having fully demonstrated their stated reactive capability.
PJM will notify the MOC or LCC for synchronous condensers that their units exceeded their stated reactive capability and will propose request that they increase the reactive capability modeled within the PJM EMS by entering New-Default eDART MVAR ticket.

**E.8.4 Units Facilities Testing Below 5% of Stated Limits**
Units or wind generating stations with test results under 5% of their stated limits for the maximum lagging test at maximum real power output and the maximum leading test at minimum real power output will not be considered as having demonstrated their stated reactive capability.
PJM will determine which units have not demonstrated their stated reactive capability due to either internal or external operational limitations based on reasons documented within the submitted test results.

For units that claimed external operational limitations,

A. PJM will perform further analysis to confirm external limitations and possible remedial measures in the event of future attempts by the MOC (or LCC for synchronous condensers) to demonstrate the unit's reactive capability.

B. If an external limitation is confirmed, PJM will provide confirmation to the MOC (or LCC for synchronous condensers) that their unit performed below their stated reactive capability due to external limitations and will not require any further action.

C. If no external limitation is confirmed, PJM will require that the MOC (or LCC for synchronous condensers) either permanently reduces the reactive capability modeled within the PJM EMS by entering a “New Default” eDART MVAR ticket or retest to demonstrate the stated capability of the unit.

D. If the MOC (or LCC for synchronous condensers) 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.

For units that claimed internal operational limitations,
A. If a facility is unable to achieve its stated capability due to an internal operational limit caused by an external condition (such as high or low transmission system voltages), the plant or the MOC (or LCC for synchronous condensers) communicated this issue to the LCC and the PJM Reliability Engineer prior to completing the test, and this communication was verified by PJM, then PJM will inform the MOC (or LCC for synchronous condensers) that their facility performed below their stated reactive capability due to external limitations and will not require any further action.

A. PJM will inform the MOC that their units performed below their stated reactive capability.

B. If the internal operational limitation was caused by an external condition such as high or low transmission system voltage, and this external condition that caused the internal operational limitation was communicated by the plant or the MOC to the LCC, and the external condition could not be mitigated by the LCC and PJM by adjusting the transmission system or other applicable actions, and PJM confirms that the internal operational limitation was caused by an external condition, then PJM will provide confirmation to the MOC that their units performed below their stated reactive capability due to external limitations and will not require any further action.

C. B. If the internal operational limitation was caused by an external condition but was not communicated by the plant or MOC (or LCC for synchronous condensers) to the LCC, and PJM, then PJM will require that the MOC (or LCC for synchronous condensers) either permanently reduce the reactive capability modeled within the PJM EMS by entering a "New Default" eDART MVAR ticket or retest to demonstrate the stated capability of the unit facility.

C. If the MOC (or LCC for synchronous condensers) chooses to retest the unit facility, PJM will require that a temporary eDART MVAR ticket be submitted that will remain active until the unit facility demonstrates the original stated capability.

D. ---

TEST EVALUATION SUMMARY
### Test Outcomes and Required Actions

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Results within 5% of Stated Limits</th>
<th>Results Outside 5% of Stated Limits</th>
<th>Initial Results at Previously UnTESTed Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Lagging at Max Output</td>
<td>None Required</td>
<td>Submit New eDart Default Reflecting Tested Values</td>
<td>Submit New eDart Default to Reflect Expected Operational Capability</td>
</tr>
<tr>
<td>Max Leading at Min Output</td>
<td>None Required</td>
<td>Submit New eDart Default to Reflect Expected Operational Capability</td>
<td>Submit New eDart Default to Reflect Expected Operational Capability</td>
</tr>
<tr>
<td>Max Leading at Max Output</td>
<td>None Required</td>
<td>Submit New eDart Default Reflecting Tested Values</td>
<td>Submit New eDart Default to Reflect Expected Operational Capability</td>
</tr>
<tr>
<td>Max Lagging at Min Output</td>
<td>None Required</td>
<td>Submit New eDart Default to Reflect Expected Operational Capability</td>
<td>Submit New eDart Default to Reflect Expected Operational Capability</td>
</tr>
</tbody>
</table>

*For Additional Details refer to text within Attachment E

### E.9 Test Tracking

Beginning in 2015, the GO (or TO for synchronous condensers) shall submit to PJM annually by January 31\textsuperscript{st} a listing of the units successfully tested within the prior five years (including test date) and also a non-binding test schedule for the current year and the next four years, which includes the applicable facility to be tested and the year the test is proposed to be completed. This information shall be submitted via the Reactive Test Schedule Form.

- [Link to Reactive Test Schedule Form](#)

### Glossary

**Scheduled Voltage**—The voltage level normally maintained at the system bus during peak load conditions.

**Gross Reactive Capability**—The maximum sustained overexcited and under-excited reactive output, which generating equipment is expected to produce under normal operating conditions.

**Net Reactive Capability at the GSU Primary**—The maximum sustained overexcited and under-excited reactive output exclusive of auxiliary usage expected to produce under normal operating conditions.

**Net Reactive Capability to the System**—The maximum sustained overexcited and under-excited reactive output exclusive of auxiliary usage and GSU reactive power losses expected to produce under normal operating conditions.

**GSU (Generator Step-Up Transformer)**—An Inductive stationary device that transfers electrical energy from generator voltage to a higher transmission voltage.

**Wind Generating Stations**—an aggregate of multiple wind turbines connected at a common bus (a.k.a. collector bus) with the outlet through a common GSU.
SAMPLE FORM - SUBMIT DATA VIA ELECTRONIC VERSION

Reactive Capability Testing Form Sheet 1

- **Test Type**: [ ] Reactive Leading Full Load  [ ] Reactive Leading Minimum Load  [ ] Reactive Lagging Full Load  [ ] Reactive Lagging Minimum Load  [ ] Real Power Verification

- **Tested By**: [ ]

- **Test Analyst Contact**: [ ]

- **Company**: [ ]

- **Plant**: [ ]

- **Unit**: [ ]

- **Data Type**: [ ] Staged  [ ] Operational

- **Point of Interconnection**

- **Telemetry Verified with PJM on**: [ ]

- **Location**: [ ]

- **Voltage**: [ ]

- **Real Power**: [ ]

- **Reactive Power**: [ ]

- **Location**: [ ]

- **Voltage**: [ ]

- **Real Power**: [ ]

- **Reactive Power**: [ ]

- **Location**: [ ]

- **Voltage**: [ ]

- **Real Power**: [ ]

- **Reactive Power**: [ ]

- **Location**: [ ]

- **Voltage**: [ ]

- **Real Power**: [ ]

- **Reactive Power**: [ ]

- **Location**: [ ]

- **Voltage**: [ ]

- **Real Power**: [ ]

- **Reactive Power**: [ ]

- **Location**: [ ]

- **Voltage**: [ ]

- **Real Power**: [ ]

- **Reactive Power**: [ ]

- **Location**: [ ]

- **Voltage**: [ ]

- **Real Power**: [ ]

- **Reactive Power**: [ ]

- **Location**: [ ]

- **Voltage**: [ ]

- **Real Power**: [ ]

- **Reactive Power**: [ ]

- **Location**: [ ]

- **Voltage**: [ ]

- **Real Power**: [ ]

- **Reactive Power**: [ ]

- **Additional Comments**: [ ]

- **Generator Voltage Schedule**: [ ]

- **Generator Voltage PT Ratio**: [ ]

- **System Voltage Schedule**: [ ]

- **System Voltage PT Ratio**: [ ]

- **GSU Nameplate Data**: [ ]

- **Tap Setting**: [ ]

- **Impedance**: [ ]

- **% Capability**: [ ]

- **MVA**: [ ]
SAMPLE FORM - SUBMIT DATA VIA ELECTRONIC VERSION

Reactive Capability Testing Form Sheet 2

Tested By: ___________________________  Submission Date _______
Test Analysis Contact: ___________________________  eDart Ticket #: ___________________________
Company: ___________________________  Unit: ___________________________
Plant: ___________________________

Summary of Requested Points

A  Sum multiple generators that are verified together or are part of the same unit. Report individual unit values separately whenever the verification measurements were taken at the individual unit. Individual values are required for units or synchronous condensers > 20 MVA.
B  Sum multiple unit auxiliary transformers.
C  Sum multiple tertiary loads, if any.
D  Sum multiple auxiliary and station service transformers.
E  If multiple points of interconnection, describe these for accurate modeling: report points individually (sum multiple auxiliary transformers).
F  High Side Net unit capability.
G  Low Side Net unit capability.

Supplemental Information for Reactive Lagging Tests at Full Load

<table>
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<tr>
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<td>45 min</td>
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<td>End of Test</td>
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Description of Additional Interconnection Points (if needed)

Remarks: (Plant Limitations)

Remarks: (System Limitations)

Remarks: (Other Limitations)
### Reactive Test Schedule Form

<table>
<thead>
<tr>
<th>Unit Name</th>
<th>Unit Type</th>
<th>Block</th>
<th>Narrate</th>
<th>Test Date</th>
<th>Test Plan</th>
<th>Test Result</th>
<th>Notes</th>
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</table>

Total Number of Units Tested per Year: 

- 1st Year: 10
- 2nd Year: 15
- 3rd Year: 12
- 4th Year: 14

<table>
<thead>
<tr>
<th>Percent of Test</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
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<td>10%</td>
<td>12%</td>
<td>12%</td>
<td>14%</td>
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</table>

*All such additions should be included in EEC company's quarterly report on Form EEC 39.*

Sheet Number: 1

*If a separate sheet is needed prior to blank, fill in number blank.*