

STANDARDS COMMITTEE
MIDWEST RELIABILITY ORGANIZATION

STANDARD APPLICATION GUIDE

MOD-025-2

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The MRO Subject Matter Expert Team is an industry stakeholder group which includes subject matter experts from MRO member organizations in various technical areas. Any materials, guidance, and views from stakeholder groups are meant to be helpful to industry participants; but should not be considered approved or endorsed by MRO staff or its board of directors unless specified.



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The Midwest Reliability Organization (MRO) Standards Committee (SC) is committed to providing training and non-binding guidance to industry stakeholders regarding existing and emerging Reliability Standards. Any materials, including presentations, were developed through the MRO SC by Subject Matter Experts (SMEs) from member organizations within the MRO region.

In 2018, SMEs in the field of asynchronous generation operation and modeling were brought together to prepare a guide for complying with North American Electric Reliability Corporation (NERC) Reliability Standard MOD-025-2 - Verification and Data Reporting of Generator Real and Reactive Power Capability and Synchronous Condenser Reactive Power Capability. Participants include representatives from Generator Owners (GOs), Generator Operators (GOPs), Transmission Owners (TOs), Transmission Operators (TOPs) and Transmission Planners (TPs).

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The materials have been reviewed by MRO staff and provide reasonable application guidance for the standard(s) addressed. Ultimately, demonstrating compliance depends on a number of factors including the precise language of the standard, the specific facts and circumstances, and quality of evidence.

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Acknowledgement

This publication was developed by a team of SMEs from MRO member organizations within the MRO footprint. The development of SME teams is an ongoing effort to produce unified application guides for MRO and its Registered Entities.

The MOD-025-2 SME Team Chair, Jessie Kiddoo (Great River Energy), wishes to acknowledge and thank those who dedicated efforts and contributed significantly to this publication. The MRO, MRO SC and their organizational affiliations include:

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INTRODUCTION

The purpose of this Standard Application Guide (SAG) for NERC Reliability Standard MOD-025-2 - Verification and Data Reporting of Generator Real and Reactive Power Capability and Synchronous Condenser Reactive Power Capability is to provide additional guidance on the implementation of MOD-025-2 to Generator Owners (GOs) of asynchronous dispersed power producing resources identified through Inclusion I4 of the Bulk Electric System definition.

OVERVIEW

This SAG focuses on the Real Power and Reactive Power verification requirements of MOD-025-2, Attachment 1 and data reporting requirements specified in Attachment 2 for asynchronous dispersed power producing resources identified through Inclusion I4 of the Bulk Electric System definition¹ such as wind generation facilities, photovoltaic generation facilities, etc. The intention of this SAG is to provide additional clarifications, techniques and recommendations on how to accomplish the verification of Real Power and Reactive Power successfully while providing useful data to the Transmission Planner (TP).

METHODOLOGY

This SAG contains clarifications, techniques and recommendations, collectively the 'suggested methodology', to adhere to the requirements of the MOD-025-2. These methods represent the intended best practices of members of the MRO MOD-025-2 Subject Matter Expert Team (SMET).

Common Terms and Definitions

This SAG uses terms defined in the NERC Glossary of Terms used in NERC Reliability Standards, updated July 03, 2018². Where the MRO MOD-025-2 SMET introduced terms not defined by NERC, as necessary, inline definitions or narratives around the intent of those terms has been provided.

¹ NERC Project 2010-17 Definition of Bulk Electric System (Phase 2), updated Nov 21, 2013.
<https://www.nerc.com/pa/RAPA/BES%20DL/BES%20Definition%20Approved%20by%20FERC%203-20-14.pdf>

² NERC Glossary of Terms used in NERC Reliability Standards, updated July 03, 2018.
https://www.nerc.com/pa/Stand/Glossary%20of%20Terms/Glossary_of_Terms.pdf

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**Evaluating MOD-025-2, Section 4 - Applicability
Analysis or Recommended Application Guidance:**

As previously stated, the scope of this MOD-025-2 SAG is the Generator Owner (GO) of asynchronous dispersed power producing resources identified through Inclusion I4 of the Bulk Electric System definition³, as identified in MOD-025-2, Section 4.2.3 Generating plant/Facility greater than 75 MVA (gross aggregate nameplate rating) directly connected to the Bulk Electric System.

Although not identified in the MOD-025-2 Section 4. Applicability, the TP for the GO is the functional entity who receives the data on the Real Power and Reactive Power verifications.

**Evaluating MOD-025-2, Section 5 – Effective Date
Analysis or Recommended Application Guidance:**

MOD-025-2, Section 5 provides the implementation requirements for testing applicable Facilities relative to the effective date of the standard. During the first interval of verification of Real Power and Reactive Power capability, MRO Registered Entities must verify Real Power and Reactive Power capability through an actual staged test, not through the use of historical operating data. The verification percentage to meet the implementation requirements is based on the total number of applicable generation facilities owned and registered under a single NERC Compliance Registry (NCR) number.

Although the Standard and Requirements are enforceable July 1, 2014, Registered Entities in the United States had until July 1, 2016 to complete the first 40% of the verifications. The following table details when Registered Entities shall have completed the associated percentage of staged tests per the implementation plan:

U.S. Effective Date	Percentage of Staged Tests Completed
1 July, 2016	40%
1 July, 2017	60%
1 July, 2018	80%
1 July, 2019	100%

Additional guidance and clarification for phased implementation of standards can be found in the NERC ERO Enterprise CMEP Practice Guide: Phased Implementation Plans with Completion Percentages.⁴

³ NERC Project 2010-17 Definition of Bulk Electric System (Phase 2), updated Nov 21, 2013.
<https://www.nerc.com/pa/RAPA/BES%20DL/BES%20Definition%20Approved%20by%20FERC%203-20-14.pdf>

⁴ NERC ERO Enterprise CMEP Practice Guide: Phased Implementation Plans with Completion Percentages, updated March 24, 2017. https://www.nerc.com/pa/comp/guidance/CMEPPPracticeGuidesDL/CMEP_Practice_Guide_Phased_Implementation_Completion_Percentages.pdf#search=phased%20implementation%20plans



Evaluating MOD-025-2, Requirements

Analysis or Recommended Application Guidance:

Requirement R1 has two distinct sections:

1. GOs must verify the Real Power capability of their dispersed power producing resources identified through Inclusion I4 of the Bulk Electric System definition as specified in Attachment 1 of MOD-025-2.
2. GOs must submit the results of the verification to its applicable TP within 90 calendar days of either a staged test or the date the operational data is chosen. This Real Power verification data must be submitted using the form specified in Attachment 2 of MOD-025-2 or similar. For more information on verification date, refer to 'Evaluating MOD-025-2, Attachment 1- Verification' in this SAG.

Requirement R2 has two distinct sections:

1. GOs must verify the Reactive Power capability of their dispersed power producing resources identified through Inclusion I4 of the Bulk Electric System definition⁵ as specified in Attachment 1 of MOD-025-2. It should be noted that this verification includes the individual asynchronous generating units as well as all additional Reactive Power compensation equipment including (but not limited to) any: shunt capacitors, shunt reactors, static var compensators, synchronous condensers, etc.
2. GOs must submit the results of said verification to the applicable TP within 90 calendar days of either a staged test or the date the operational data is chosen. This Reactive Power verification data must be submitted using the form specified in Attachment 2 of MOD-025-2 or similar. For more information on verification date, refer to 'Evaluating MOD-025-2, Attachment 1- Verification' in this SAG.

Requirement R3 is not in scope for this MOD-025-2 SAG.

Evaluating MOD-025-2, Attachment 1

There are three distinct parts of the MRO MOD-025-2 SMET's evaluation of Attachment 1: Periodicity for conducting new verification; verification specifications for applicable Facilities; and Section Notes. Each section is broken out, and the applicable elements for each section are extracted.

Evaluating MOD-025-2, Attachment 1 - Periodicity

Analysis or Recommended Application Guidance:

The first verification of Real Power and Reactive Power capability for an asynchronous dispersed power producing resource identified through Inclusion I4 of the Bulk Electric System definition is required to be a staged test. Subsequent verifications of the applicable Facility can be staged or use operational data.

It is recommended to develop a D-curve that aggregates all of the individual elements included in the facility and adjusted to model the capacity of the Facility (refer to Appendix B for further explanation

⁵ NERC Project 2010-17 Definition of Bulk Electric System (Phase 2), updated Nov 21, 2013.

<https://www.nerc.com/pa/RAPA/BES%20DL/BES%20Definition%20Approved%20by%20FERC%203-20-14.pdf>



around developing a facility D-curve). The staged test results should be compared against the D-curve. In the event that the results of the first staged test were unduly restricted (so that they did not demonstrate at least 50 percent of the reactive capability of the facility) as a result of unusual generation or equipment limitations (e.g., capacitor or reactor banks out of service), then the next verification will be by another staged test.

MOD-025-2, Periodicity section requires each new asynchronous dispersed power producing resource identified through Inclusion I4 of the Bulk Electric System definition to be verified within 12 calendar months of its commercial operation date. The MRO MOD-025-2 SMET recommends using the commercial operation date as specified in a generation facility's interconnection agreement to establish the first verification. A "commercial operation date"⁶ is defined by FERC as:

- **Commercial Operation Date:** *of a unit shall mean the date on which the Generating Facility commences Commercial Operation as agreed to by the Parties pursuant to Appendix E to the Standard Large Generator Interconnection Agreement.*
- **Commercial Operation:** *shall mean the status of a Generating Facility that has commenced generating electricity for sale, excluding electricity generated during Trial Operation.*
- **Trial Operation** *shall mean the period during which Interconnection Customer is engaged in on-site test operations and commissioning of the Generating Facility prior to Commercial Operation*

Reverification of Real Power and Reactive Power of asynchronous dispersed power producing resources identified through Inclusion I4 of the Bulk Electric System definition can either be completed via staged testing or through the use of operational data. Under MOD-025-2, Attachment 1, section labeled "Verification specifications for applicable Facilities", point 2, operational data must be no older than two years from the verification date and must be submitted within 90 days of when the GO chose the operational data to be submitted to the TP.

MOD-025-2, Periodicity section requires reverification to occur as follows:

- Every five years with no more than 66 calendar months between verifications. Therefore, if a GO completed its Real Power and Reactive Power verification on January 01, 2018, the next verification would have to occur on or before June 30, 2023.
- As noted in MOD-025-2, Attachment 1, section labeled "Verification specifications for applicable Facilities", point 2.1.2 states that a dispersed power producing resource has to have 90% of wind turbines or photovoltaic inverters participating in the verification. If this is not the case the verification must be rescheduled within six-months.
- It is intended that Real Power testing be performed at the same time as full load (i.e. maximum load) Reactive Power testing, however separate testing is allowed for this standard. Further expansion of this statement will be addressed in the next section of this SAG.
- Within 12 months of a discovery of a change in capability of more than 10 percent that is expected to last longer than six months.

⁶ FERC Standard Large Generator Interconnection Agreement, updated September 26, 2016.

<https://www.ferc.gov/industries/electric/indus-act/gi/stnd-gen.asp>



- A change is considered to be something that affects Real Power and/or Reactive Power capability by greater than ten percent of the previous verification. This can include, for asynchronous dispersed power producing resources identified through Inclusion I4 of the Bulk Electric System definition, equipment such as: individual generators, individual photovoltaic panels/inverters, Reactive Power compensation equipment (shunt capacitors, shunt reactors, dynamic VAR compensators, etc.), etc. As a general consideration, a responsible entity could use its Facility Ratings, as developed pursuant to NERC Reliability Standard FAC-008-3 - Facility Ratings⁷, to determine the magnitude of the change and whether or not it meets the greater than ten percent threshold in conjunction with its previous Real Power and Reactive Power verification.

**Evaluating MOD-025-2, Attachment 1- Verification, Sections 1 through 5
Analysis or Recommended Application Guidance:**

Please note – Analysis and recommend application guidance in this section of the SAG will be conducted by the numeric sections as outlined in MOD-025-2 Attachment 1, Verification Section.

1. Individual generating units of dispersed power producing resources identified through Inclusion I4 of the Bulk Electric System definition.
2. Perform Reactive Power verification with the automatic voltage regulator (AVR) in service and controlling voltage or in a different control mode as instructed by the Transmission Operator, as applicable and allowed for in NERC Reliability Standard VAR-002-4.1 - Generator Operation for Maintaining Network Voltage Schedules⁸.

All auxiliary equipment should be in normal operating mode during testing. The tests are meant to reflect actual performance, so auxiliary equipment should not be operating in manual mode or turned off if that is not normally the case. Auxiliary equipment includes, but is not limited to, devices such as shunt reactors, shunt capacitors, static var compensators, automatic on-load tap changers, synchronous condensers, and any other device that provides Reactive Power compensation.

Section R1 defines the verification date as the date the data is recorded for a staged test; or the date the data is selected for verification using historical operational data. Staged tests *must* be used during initial plant verification, and can be used to re-verify every 5 years (as defined by MOD-025-2). Historical operational data cannot be used during initial verification. It should be noted that when using historical operational data, the verification date is intended to be the date the GO selects the historical operational data to submit, not the date(s) the operational data occurred. The operational data cannot be any older than two years from the verification date. If historical operational data is selected on different days, denote the earliest selection date as the verification date on the Attachment 2 form.

⁷ NERC Standard FAC-008-3 – Facility Ratings, Updated Nov 21, 2013.
<https://www.nerc.com/pa/Stand/Reliability%20Standards/FAC-008-3.pdf>

⁸ NERC Reliability Standard VAR-002-4.1 — Generator Operation for Maintaining Network Voltage Schedules., updated Sept 26, 2017 <http://www.nerc.com/pa/Stand/Reliability%20Standards/VAR-002-4.1.pdf>

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The table below details the options for submitting verification data for MOD-025-2 (Figure 1).

Verification	Description	Data Collection Options	Periodicity
Initial Verification	Initial verification for MOD-025-2 ⁹	Staged Test	1 st year only (within 12 months of commercial operation date)
Reverification	Reverification after 5 years of operation	Staged Test	5 years (no more than 66 months)
		Operational Data	5 years (no more than 66 months)
	Change in plant capability (more than 10% of last recorded capability)	Staged Test	One time test. Must be completed within 12 months following discovery of change
		Operational Data	One time test. Must be completed within 12 months following discovery of change

Figure 1.

2.1. It is recommended that the Generator Owner test maximum lagging Reactive Power capability at a Real Power level that will allow them to achieve full lagging Reactive Power capability based on the D-curve.

2.1.1. Not applicable to this SAG.

2.1.2. Wind and PV are exempt from over-excited (lagging) at minimum real power and all under-excited (leading) reactive capability testing. Dispersed power producing resources identified through Inclusion 14 of the Bulk Electric System definition are not required to test at full Real Power capability. This SAG SMET recommends testing at a real power level that allows them to achieve full lagging Reactive Power capability based upon the D-curve. More specifically, the GO should be able to demonstrate its ability to meet the power factor requirements outlined in its FERC Standard Large Generator Interconnection Agreement, Appendix G.

2.2. Not applicable to this SAG

2.3. Not applicable to this SAG

2.4. No further guidance

3. Record the following data for the verifications specified above:

3.1. The value of the gross Real and Reactive Power generating capabilities as soon as ONE of following limits is reached:

- Maximum MVA rating;
- Maximum allowable temperature rise;
- Machine terminal or inverter output voltage upper limit;

⁹ Initial verification refers to the first MOD-025-2 form submitted for every applicable facility. This includes testing to meet requirements outlined in the Effective Date section, or new plant verification.



- Point of Interconnection voltage upper limit;
- Power plant transformer(s) on-load tap changer (if equipped) lower limit;
- AVR or plant voltage controller upper limit.

The above is not an exhaustive list; there might be other limits which may constrain Real and Reactive Power capabilities. A responsible entity should review its documentation developed for the following NERC Reliability Standards:

- NERC Reliability Standard FAC-008-3 — Facility Ratings¹⁰
- NERC Reliability Standard PRC-019-2 — Coordination of Generating Unit or Plant Capabilities, Voltage Regulating Controls, and Protection¹¹
- NERC Reliability Standard PRC-024-2 — Generator Frequency and Voltage Protective Relay Settings¹²
- NERC Reliability Standard PRC-025-2 – Generator Relay Loadability¹³

3.2. Data available from VAR-001-4.2 – Voltage and Reactive Control¹⁴ and VAR-002-4.2 – Generator Operation for Maintaining Network Voltage Schedules¹⁵.

3.3. No further guidance

3.4. The ambient conditions, if applicable, at the end of the verification period that the Generator Owner requires to perform corrections to Real Power for different ambient conditions such as:

- Ambient air temperature
- Relative Humidity
- Wind speed
- Irradiance

3.5. No further guidance

3.6. No further guidance

3.7. No further guidance

3.8. No further guidance

4. No further guidance

¹⁰ NERC Reliability Standard FAC-008-3 — Facility Ratings. <http://www.nerc.com/pa/Stand/Reliability%20Standards/FAC-008-3.pdf>

¹¹ NERC Reliability Standard PRC-019-2 — Coordination of Generating Unit or Plant Capabilities, Voltage Regulating Controls, and Protection. <http://www.nerc.com/pa/Stand/Reliability%20Standards/PRC-019-2.pdf>

¹² NERC Reliability Standard PRC-024-2 — Generator Frequency and Voltage Protective Relay Settings. <http://www.nerc.com/pa/Stand/Reliability%20Standards/PRC-024-2.pdf>

¹³ NERC Reliability Standard PRC-025-2 – Generator Relay Loadability. <https://www.nerc.com/pa/Stand/Reliability%20Standards/PRC-025-2.pdf>

¹⁴ NERC Standard VAR-001-4.2 – Voltage and Reactive Control, updated Sept 26, 2017, <https://www.nerc.com/pa/Stand/Reliability%20Standards/VAR-001-4.2.pdf>

¹⁵ NERC Reliability Standard VAR-002-4.1 — Generator Operation for Maintaining Network Voltage Schedules., updated Sept 26, 2017 <http://www.nerc.com/pa/Stand/Reliability%20Standards/VAR-002-4.1.pdf>



4.1. No further guidance

5. Note that MW values to be adjusted and tested should be within the capability boundary of a generator output.

Evaluating MOD-025-2, Attachment 1- Notes

Please note – Analysis and recommend application guidance in this section of the SAG will be conducted by the numbers as outlined in MOD-025-2 Attachment 1, Verification Section Notes.

Analysis or Recommended Application Guidance:

Note 1: The thermal capability curve (D-curve) of a dispersed power producing resource similar to a synchronous machine provided by the manufacturer is typically obtained under the rated (or nominal) voltage condition, however the data points obtained by the Reactive Power verification required by MOD-025-2 may not duplicate the curve because the output voltage is often different than the rated voltage (1.0 p.u.) during testing/verification. For example, if voltage at the POI is higher than 1.0 p.u. during testing/verification, the recorded data points may not be shown on the D-curve developed at 1.0 p.u. voltage.

Note 2: It is a sound practice to perform engineering analyses to determine expected applicable Facility capabilities before and after the verification to evaluate the impact of system voltages on capability curves. Appendix B provides an example of calculating a Facility capability curve from manufacturer data.

Note 3: Verification of leading capabilities for asynchronous machines such as wind turbines, Photovoltaic generation resources, etc. are not required by the standard. For vintage wind turbines (Type I and Type II) there will likely be minimum lagging capabilities available due to the technology limitations when they were installed.

Note 4: Note 4 is not applicable to this SAG.

Evaluating MOD-025-2, Attachment 2

Analysis or Recommended Application Guidance:

One-line Diagram, Table, and Summary for Verification Information Reporting

Note: If the configuration of the applicable Facility does not lend itself to the use of the diagram, tables, or summaries for reporting the required information, changes may be made to this form, provided that all required information identified in MOD-025-2 Attachment 1 is reported.

Company:

Reported By (name):

Plant: Unit No.:

Date of Report:

Check all that apply:

- Over-excited Maximum Load Reactive Power Verification
- Under-excited Maximum Load Reactive Power Verification
- Over-excited Minimum Load Reactive Power Verification
- Under-excited Minimum Load Reactive Power Verification
- Real Power Verification
- Staged Test Data
- Operational Data

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**Analysis or Recommended Application Guidance:
MOD-025—Attachment 2 (cont.)**

Simplified one-line diagram for asynchronous resource showing plant auxiliary Load connections and verification data (Figure 2).

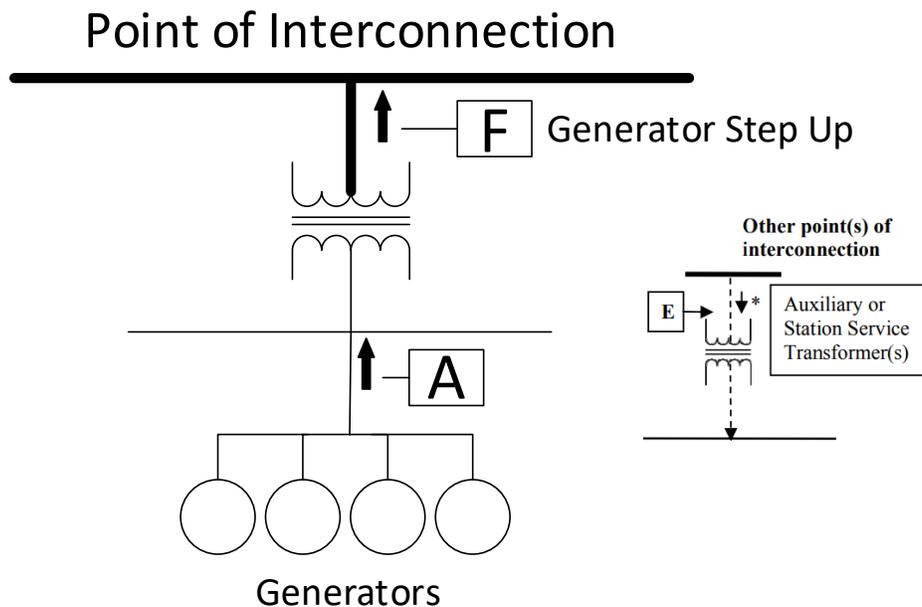


Figure 2.



**Analysis or Recommended Application Guidance:
MOD-025—Attachment 2 (cont.)**

Standard MOD-025-2 — Verification and Data Reporting of Generator Real and Reactive Power Capability and Synchronous Condenser Reactive Power Capability (Figure 3).

Point	Voltage	Real Power	Reactive Power	Comment
A	kV	MW	Mvar	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.
Identify calculated values, if any:				
B	N/A kV	N/A MW	N/A Mvar	Sum multiple unit auxiliary transformers.
Identify calculated values, if any:				
C	N/A kV	N/A MW	N/A Mvar	Sum multiple tertiary Loads, if any.
Identify calculated values, if any:				
D	N/A kV	N/A MW	N/A Mvar	Sum multiple auxiliary and station service transformers.
Identify calculated values, if any:				
E	kV	MW	Mvar	If multiple points of Interconnection, describe these for accurate modeling; report points individually (sum multiple auxiliary transformers).
F	kV	MW	Mvar	Net unit capability
Identify calculated values, if any.				

Figure 3.

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**Analysis or Recommended Application Guidance:
MOD-025—Attachment 2 (cont.)**

Verification Data

Provide data by unit of Facility, as appropriate

Data Type	Data Recorded	Last Verification (Previous Data; will be blank for the initial verification)
Gross Reactive Power Capability (*Mvar)		
Aux Reactive Power (*Mvar)	N/A	N/A
Net Reactive Power Capability (*Mvar) equals Gross Reactive Power Capability (*Mvar) minus Aux Reactive Power connected at the same bus (*Mvar) minus tertiary Reactive Power connected at the same bus (*Mvar)		
Gross Real Power Capability (*MW)		
Aux Real Power (*MW)	N/A	N/A
Net Real Power Capability (*MW) equals Gross Real Power Capability (*MW) minus Aux Real Power connected at the same bus (*MW) minus tertiary Real Power connected at the same bus (*MW)		
*Note: Enter values at the end of the verification period.		
GSU losses (only required if verification measurements are taken on the high side of the GSU - Mvar)		

Summary of Verification

- Date of Verification _____, Verification Start Time _____, Verification End Time _____
- Scheduled Voltage _____
- Transformer Voltage Ratio: GSU _____, Unit Aux _____, Station Aux _____, Other Aux _____
- Transformer Tap Setting: GSU _____, Unit Aux _____, Station Aux _____, Other Aux _____
- Ambient conditions at the end of the verification period:
 - Air temperature: _____
 - Humidity: _____
 - Cooling water temperature: _____ N/A _____
 - Other data as applicable: _____
- Generator hydrogen pressure at time of test (if applicable) _____ N/A _____

Date that data shown in last verification column in table above was taken _____

Remarks:

Note: If the verification value did not reach the thermal capability curve (D-Curve), describe the reason.

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Other Considerations and Recommendations:

Testing

If the Reactive Power capability is verified through testing, coordination with the TOP should occur to ensure voltage is maintained within steady-state limits. If the Reactive Power verification testing will cause the dispersed power producing resources identified through Inclusion I4 of the Bulk Electric System definition voltage to deviate outside of the prescribed voltage schedule, the GOP should notify its TOP per the requirements of NERC Reliability Standard VAR-002-4.1 — Generator Operation for Maintaining Network Voltage Schedules¹⁶.

Testing during the summer months is recommended to minimize negative impacts of Ambient Air Temperature and Relative Humidity as recorded in MOD-025-2 Attachment 1, Section 3.4.

Other

Attachment 1 Section 1 guidance: Either individual unit or aggregate data may be provided. A combination of individual unit data and aggregate data may provide useful information on the gains and losses of the dispersed power producing resource.

Additionally, data from the required MOD-025-2 could prove to be useful for the documentation as required by the following NERC Reliability Standards:

- NERC Reliability Standard FAC-008-3 — Facility Ratings¹⁷
- NERC Reliability Standard PRC-019-2 — Coordination of Generating Unit or Plant Capabilities, Voltage Regulating Controls, and Protection¹⁸
- NERC Reliability Standard PRC-024-2 — Generator Frequency and Voltage Protective Relay Settings¹⁹
- NERC Reliability Standard PRC-025-2 – Generator Relay Loadability²⁰

¹⁶ NERC Reliability Standard VAR-002-4.1 — Generator Operation for Maintaining Network Voltage Schedules., updated Sept 26, 2017 <http://www.nerc.com/pa/Stand/Reliability%20Standards/VAR-002-4.1.pdf>

¹⁷ NERC Reliability Standard FAC-008-3 — Facility Ratings.
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¹⁸ NERC Reliability Standard PRC-019-2 — Coordination of Generating Unit or Plant Capabilities, Voltage Regulating Controls, and Protection. <http://www.nerc.com/pa/Stand/Reliability%20Standards/PRC-019-2.pdf>

¹⁹ NERC Reliability Standard PRC-024-2 — Generator Frequency and Voltage Protective Relay Settings.
<http://www.nerc.com/pa/Stand/Reliability%20Standards/PRC-024-2.pdf>

²⁰ NERC Reliability Standard PRC-025-2 – Generator Relay Loadability.
<https://www.nerc.com/pa/Stand/Reliability%20Standards/PRC-025-2.pdf>



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The MRO Subject Matter Expert Team is an industry stakeholder group which includes subject matter experts from MRO member organizations in various technical areas. Any materials, guidance, and views from stakeholder groups are meant to be helpful to industry participants; but should not be considered approved or endorsed by MRO staff or its board of directors unless specified.



APPENDIX B: DEVELOPMENT OF FACILITY D-CURVE

A generator capability curve, better known as D-curve is a representation of a generator's Reactive Power capability (Q) at any given Real Power (P) point within the generator Real Power capability during steady-state operation. The D-curve represents Q in both leading and lagging capability.

When considering individual generating units of dispersed power producing resources identified through Inclusion 14 of the Bulk Electric System definition, each individual generating unit will have its own D-curve, and it is possible that these D-curves could differ if the individual generating units are not identical. In these instances, the idea of an aggregate D-curve for the aggregate generation facility becomes more complicated especially if this facility contains shunt reactive power equipment (capacitors and/or reactors) and static VAR-compensators.

Calculating a Gross D-curve

Developing a gross D-curve for a facility can be a simple process that consists of aggregating the reactive power capability of the individual Elements that comprise the facility. For example, an asynchronous generation facility, Hypothetical Wind I, LLC (HWI), consists of the following Elements:

- Wind Turbine Generator: 1MW, ± 0.5 Mvar and 100 quantity
 - 0 – 0.25MW = ± 0.25 Mvar
 - 0.26 – 1.0MW = ± 0.5 Mvar
- Shunt reactor bank: -10Mvar
- Shunt Capacitor bank: +15Mvar
- Static VAR Compensator: ± 8 Mvar

Considering the above generation facility information, the following is true of the gross D-curve (Figure 4):

- 0 – 25.0MW = -43Mvar (leading)
- 0 – 25.0MW = +48Mvar (lagging)
- 25.1 – 100MW = -68Mvar (leading)
- 25.1 – 100MW = +73Mvar (lagging)

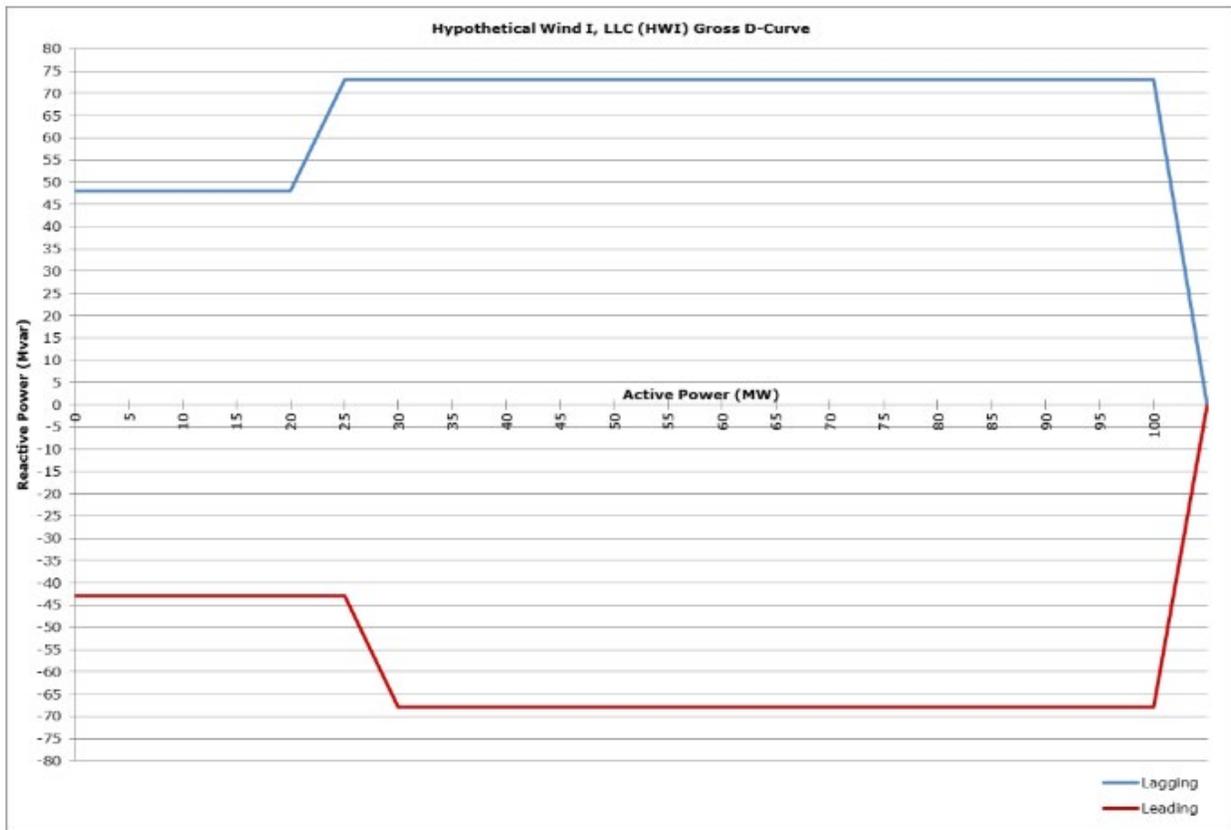


Figure 4.

Determining a Net D-Curve

The purpose of MOD-025-02 is to identify Real and Reactive Power that is available for maintaining a reliable Bulk Electric System. Developing a net D-curve for a facility is much more challenging for dispersed power producing resources identified through Inclusion I4 of the Bulk Electric System definition. This is because all of the other necessary equipment; including underground conductors, overhead conductors, bus work, transformers, etc. This additional equipment produces losses and consideration should be given to surge impedance loading. When considering these additional factors, a net D-curve is more difficult to produce, but not impossible. Most modern asynchronous dispersed power producing resources identified through Inclusion I4 of the Bulk Electric System definition require a load flow and Reactive Power compensation study to determine the required Reactive Power compensation equipment to meet its required power factor requirements as specified in its applicable interconnection agreement. These studies can serve as an excellent source to determine the theoretical net D-curve.

However, if these studies are not available, a gross D-curve can be used in tandem with the first Reactive Power verification. The information gained from these two sources can then be used to determine the net D-curve and considered as establishing a base-line.