UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

Reactive Power Requirements for Non-Synchronous Generation	**)** **)**	**Docket No. RM16-1-000**

COMMENTS OF THE NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION IN RESPONSE TO NOTICE OF PROPOSED RULEMAKING

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NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION
IN RESPONSE TO NOTICE OF PROPOSED RULEMAKING

The North American Electric Reliability Corporation ("NERC")[1] hereby provides these comments in support of the Federal Energy Regulatory Commission's ("FERC" or the "Commission") November 19, 2015 Notice of Proposed Rulemaking ("NOPR")[2] proposing to revise the Standard Generator Interconnection Agreements to eliminate the exemptions for wind generators from the requirement to provide reactive power by revising the *pro forma* Large Generator Interconnection Agreement ("LGIA"), Appendix G to the *pro forma* LGIA, and the *pro forma* Small Generator Interconnection Agreement ("SGIA").

I. BACKGROUND

On November 19, 2015, FERC issued a NOPR proposing to revise two *pro forma* interconnection agreements, the LGIA and the SGIA, to eliminate the current exemption for wind generators from the requirement to provide reactive power, thereby requiring all newly interconnecting generators (i.e., new generators seeking to interconnect to the transmission system and all existing non-synchronous generators making upgrades to their generation facilities that require new interconnection requests), both synchronous and non-synchronous, to

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[1] The Federal Energy Regulatory Commission certified NERC as the electric reliability organization ("ERO") authorized by Section 215 of the Federal Power Act, in its order issued on July 20, 2006, in Docket No. RR06-1-000. *See Order Certifying North American Electric Reliability Corporation as the Electric Reliability Organization and Ordering Compliance Filing*, 116 FERC ¶ 61,062 (2006), *order on reh'g and compliance*, 117 FERC ¶ 61,126 (2006), *aff'd sub nom. Alcoa Inc. v. FERC*, 564 F.3d 342 (D.C. Cir. 2009).
[2] *Proposal to Revise Standard Generator Interconnection Agreements,* 153 FERC ¶ 61,175 (2015) ("NOPR").

provide reactive power.[3] As noted in the NOPR, the existing *pro forma* LGIA and *pro forma* SGIA both require, as a condition of interconnection, an interconnecting generator to design its generating facility to maintain a composite power delivery at continuous rated power output at the Point of Interconnection ("POI") at a power factor of 0.95 leading to 0.95 lagging, or a different range if adopted by the Transmission Provider.[4] Wind generators have been exempted from this reactive power requirement absent a study finding the provision of reactive power necessary, because historically, the costs for an interconnection customer to design and build a wind generator that could provide reactive power were high and could have created an obstacle to the development of wind generation.[5] However, as noted in the Commission's NOPR, with technological advancements, wind generators can now provide reactive power more cheaply, and the cost of providing reactive power no longer presents an obstacle to the development of wind generation.[6]

The Commission states in the NOPR that its proposal would create comparable reactive power requirements for non-synchronous and synchronous generators, except that non-synchronous generators will only be required to maintain the required power factor range when the generator's real power output exceeds 10 percent of its nameplate capacity.[7] Additionally, the Commission states that the NOPR proposal seeks to ensure that all generators, synchronous and non-synchronous, are treated in a not unduly discriminatory or preferential manner, as required by Sections 205 and 206 of the Federal Power Act ("FPA"), and to ensure sufficient

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[3] NOPR at P 2.
[4] *Id*.
[5] *Id*.
[6] *Id.*, citing to *Payment for Reactive Power*, Commission Staff Report, Docket No. AD14-7, app. 2, at 1-3 (Apr. 22, 2014).
[7] NOPR at P 1.

reactive power is available on the electric grid as more non-synchronous generators seek to interconnect.[8] With respect to reliability, the Commission explicitly notes the following:

> [A]s the penetration of wind generation continues to grow, exempting a class of generators from providing reactive power could create reliability issues if those generators represent a substantial amount of total generation, or if many of the resources that currently provide reactive power are retired from operation. Local reliability issues, due to the short distances that reactive power can be transmitted, that are not readily apparent given the current generation mix could result if a region were to lose synchronous resources that supply reactive power and the resulting generation mix consisted of a significant quantity of resources that were exempt from providing reactive power. Further, the Commission believes that maintaining this exemption may unduly place the burden of supplying reactive power on synchronous generators without a reasonable technological or cost-based distinction between synchronous and non-synchronous generators.[9]

Accordingly, the Commission preliminarily concludes that the continued exemption from the reactive power requirement for newly interconnecting wind generators is unjust and unreasonable and unduly discriminatory and preferential.[10] The Commission is therefore proposing to revise the LGIA and SGIA to eliminate the exemptions for wind generators from the reactive power requirement.[11]

II. <u>NOTICES AND COMMUNICATIONS</u>

Notices and communications with respect to this filing may be addressed to the following:[12]

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[8] NOPR at P 3.
[9] NOPR at P 11, citing to *PJM Interconnection, L.L.C.*, 151 FERC ¶61,097, at P 7 (2015); *Payment for Reactive Power*, Commission Staff Report, Docket No. AD14-7, app. 2, at 1-3 (Apr. 22, 2014).
[10] NOPR at P 12.
[11] *Id*.
[12] Persons to be included on the Commission's service list are identified by an asterisk. NERC respectfully requests a waiver of Rule 203 of the Commission's regulations, 18 C.F.R. § 385.203 (2015), to allow the inclusion of more than two persons on the service list in this proceeding.

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III. COMMENTS

As articulated in detail in the attached *NERC White Paper on FERC NOPR Proposal to Revise Standard Generator Interconnection Agreements*, included as **Attachment A** to these comments, NERC supports the Commission's proposal to eliminate the exemptions for wind generators from the requirement to provide reactive power, therefore requiring all non-synchronous generation resources to provide reactive power capability. NERC agrees with the Commission's concern that, as the penetration of wind generation continues to grow, exempting a class of generators from providing reactive power could create reliability issues if those generators represent a substantial amount of total generation, or if many of the resources that currently provide reactive power are retired from operation.[13] NERC also agrees with the Commission's concern that local reliability issues, due to the short distances that reactive power can be transmitted, that are not readily apparent given the current generation mix could result if a region were to lose synchronous resources that supply reactive power and the resulting

[13] NOPR at P 11.

generation mix consisted of a significant quantity of resources that were exempt from providing reactive power.[14]

Part of NERC's mission, as the Commission-certified ERO, is to assess seasonal and long-term reliability of the Bulk-Power System. In furtherance of this mission, the NERC Planning Committee and Operating Committee jointly created the Essential Reliability Services Task Force ("ERSTF") in 2014 to consider the issues that may result from the changing generation resource mix. In a report issued by the ERSTF in December 2015, the importance of understanding and preparing for the change in resource mix, which includes the increased use of variable energy resources, the retirement of conventional generating units, advances in distributed energy resources, and other changes to traditional generation resources, is highlighted.[15] The report found that new generation resources must provide adequate levels of frequency support, ramping capability, and voltage control to maintain the reliability of the Bulk-Power System during its ongoing transformation. In particular, the ERSTF report recommended the following:

- All resources should support frequency and voltage;
- Industry should monitor essential reliability services and investigate trends in frequency support, ramping capability, and voltage support;
- NERC should evaluate the impact of distributed energy resources on the Bulk-Power System and how these resources affect essential services; and
- Industry practices should enhance the reliability of the Bulk-Power System with adequate levels of essential reliability services as the resource mix evolves.[16]

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[14] NOPR at P 11.

[15] *See*, *Essential Reliability Services Task Force Measures Framework Report* (Dec. 2015), available at: http://www.nerc.com/comm/Other/essntlrlbltysrvcstskfrcDL/ERSTF%20Framework%20Report%20-%20Final.pdf.

[16] *Id.*, at v.

FERC's NOPR proposal would advance the recommendations in the ERSTF report by creating comparable reactive power requirements for non-synchronous and synchronous generators, which would help to ensure that sufficient reactive power is available on the electric grid as more non-synchronous generators seek to interconnect. As noted in the ERSTF report, a consistent and controlled voltage profile must be maintained to protect system reliability and transfer large amounts of active power across the grid in both normal operations and following a disturbance.[17] Because voltage issues tend to be local in nature, such as in sub-areas of the transmission and distribution systems, sufficient reactive power is needed to keep active power flowing and maintain necessary voltage levels.[18] The Commission's NOPR proposal would therefore help to support the goal of ensuring that generators, including variable energy resources such as wind and solar, are able to provide dynamic reactive capability to support Bulk-Power System voltages and maintain reliability. Elimination of the exemption would also avoid the potential burden on synchronous generators that could exist should the exemption not be eliminated—that is, that synchronous generators would unduly bear the burden of supplying reactive power without a reasonable technological or cost-based distinction between synchronous and non-synchronous generators.[19]

Provided below are summary responses to the questions raised in the NOPR proposal. A detailed technical explanation for each of these responses is included in the attached *NERC White Paper on FERC NOPR Proposal to Revise Standard Generator Interconnection Agreements*, included as **Attachment A**, to these comments.

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[17] *Id.*, at 16-20.
[18] *Id.*
[19] *See*, NOPR at P 11.

A. Removal of Exemption

NERC agrees with the NOPR proposal to revise the *pro forma* LGIA, Appendix G of the *pro forma* LGIA, and the *pro forma* SGIA to eliminate the exemptions for wind generators from the reactive power requirements.[20] The ability to control the production and absorption of reactive power for the purposes of maintaining desired voltages is critical to the reliable and efficient operation of the Bulk-Power System. NERC considers voltage control an Essential Reliability Service to the Bulk-Power System. Furthermore, increased penetrations of non-synchronous generation that do not provide voltage support using dynamic reactive power control could increase reliability risk and may require other resources to maintain a reliable reactive power control profile. For these reasons, NERC supports removing this exemption for all non-synchronous generators. Additional technical analysis is provided in **Attachment A**, *NERC White Paper on FERC NOPR Proposal to Revise Standard Generator Interconnection Agreements*, at pages 4-5.

B. Power Factor Range

In the NOPR, FERC proposes that all newly interconnecting non-synchronous generators, and all existing non-synchronous generators proposing upgrades to their generation facilities that require new interconnection requests, would be required to design their generating facilities to maintain reactive power within a power factor range of 0.95 leading to 0.95 lagging, or the standard range established by the Transmission Provider and approved by the Commission, to be measured at the POI.[21]

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[20] NOPR at P 12.

[21] NOPR at P 13, citing to the *pro form* LGIA, which defines "Point of Interconnection" as "the point, as set forth in Appendix A to the Standard Large Generator Interconnection Agreement, where the Interconnection Facilities connect to the Transmission Provider's Transmission System." Similarly, the *pro forma* SGIA defines "Point of Interconnection" as "[t]he point where the Interconnection Facilities connect with the Transmission Provider's Transmission System."

NERC agrees with the requirement for non-synchronous generation to comply with providing a "composite power delivery at continuous rated power output at the Point of Interconnection at a power factor within the range of 0.95 leading to 0.95 lagging, unless the Transmission Provider has established different requirements that apply to all similarly situated generators in the control area on a comparable basis."[22] Review of inverter-based non-synchronous generation has identified that modern Wind Turbine Generator ("WTG") technology can provide the full range of required power factor capability when online. For situations where the WTG itself cannot meet the full power factor requirements, dynamic reactive devices such as STATCOMs or SVCs can be employed to expand reactive capability. However, it is unclear what the power factor requirement refers to explicitly with respect to power factor capability at active power outputs other than nominal. It is assumed that the non-synchronous generation must meet the 0.95 leading to 0.95 lagging power factor capability using continuously-acting dynamic reactive resources for all real power outputs above 10% of nominal. This assumes a "box"-type reactive capability range. FERC should clarify this using a reactive capability diagram for non-synchronous generation plants, as measured at the POI. In addition to the reactive capability curve, a complete specification should address the expected capabilities during off-nominal voltages. Non-synchronous generation may not, and should not necessarily, be required to provide full capability range at all operating voltages (e.g., a generator should not be required to provide full reactive power consumption when low voltage conditions are occurring at the POI). A reactive capability versus voltage characteristic would clearly address this issue and is therefore recommended. Additional technical analysis is provided in

[22] *See*, **Attachment A**, *NERC White Paper on FERC NOPR Proposal to Revise Standard Generator Interconnection Agreements*, at 5, citing to the *pro forma* SGIA at section 1.8.1.

Attachment A, *NERC White Paper on FERC NOPR Proposal to Revise Standard Generator Interconnection Agreements*, at pages 6-10.

C. Minimum Output Level for Reactive Capability

In the NOPR, the Commission requests comments on the proposed requirement that newly interconnecting non-synchronous generators only be required to produce reactive power when the generator's real power output is greater than 10 percent of nameplate capacity.[23]

FERC's proposed permissive reactive power range for low real power output is technically justified and reasonable. A 10% minimum active power output level accounts for a dispersed power producing resource such as wind or solar not being able to provide full capability range due to cycling individual units. At low output, some WTGs or PV inverters may be offline resulting in a reduction of reactive capability. Therefore, a 10% minimum output level accounts for this technology limitation while ensuring full dynamic reactive capability when attainable. Additional technical analysis is provided in **Attachment A**, *NERC White Paper on FERC NOPR Proposal to Revise Standard Generator Interconnection Agreements*, at pages 11-12.

Included in **Attachment A** are additional considerations with respect to the FERC NOPR on proposed changes to the *pro forma* SGIA and *pro forma* LGIA related to reactive power capability.[24] While FERC did not explicitly request comments on these topics, NERC staff took the opportunity to document additional technical considerations related to the topic, including solar photovoltaic considerations; voltage control vs. power factor control; dynamic vs. static

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[23] NOPR at P 18.

[24] *See*, **Attachment A**, *NERC White Paper on FERC NOPR Proposal to Revise Standard Generator Interconnection Agreements*, at 12-21.

reactive capability; removing System Impact Study requirements; voltage ride-through capability; and frequency response.

IV. CONCLUSION

For the reasons stated above, NERC supports the Commission's NOPR proposal to eliminate the exemptions for wind generators from the requirement to provide reactive power by revising the *pro forma* LGIA, Appendix G to the *pro forma* LGIA, and the *pro forma* SGIA.

Respectfully submitted,

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Date: January 27, 2016

Attachment A

NERC White Paper

NERC White Paper

On FERC NOPR [Docket No. RM16-1-000]

Proposal to Revise Standard Generator Interconnection Agreements

NERC White Paper on NOPR

In response to FERC Notice of Proposed Rulemaking (NOPR) related to "Proposal to Revise Standard Generator Interconnection Agreements" addressing reactive power requirements for non-synchronous generation, NERC provides the following technical comments:

- **Removal of Exemption:** NERC agrees that the current state of the art in non-synchronous generation technologies and declining costs of these technologies make it "unduly discriminatory" and "preferential" to non-synchronous generators. The ability to control the production and absorption of reactive power for the purposes of maintaining desired voltages is critical to the reliable and efficient operation of the bulk power system (BPS); NERC considers voltage control an Essential Reliability Service (ERS) to the BPS. Furthermore, increasing penetrations of non-synchronous generation that do not provide voltage support by dynamic reactive power control would be a reliability risk moving forward. NERC supports removing this exemption for all non-synchronous generators.
- **Power Factor Range:** NERC agrees with the requirement for non-synchronous generation to comply with providing a "composite power delivery at continuous rated power output at the Point of Interconnection at a power factor within the range of 0.95 leading to 0.95 lagging, unless the Transmission Provider has established different requirements that apply to all similarly situated generators in the control area on a comparable basis." Review of inverter-based non-synchronous generation has identified that modern Wind Turbine Generator (WTG) technology can provide the full range of required power factor capability when online. For situations where the WTG itself cannot meet the full power factor requirements, dynamic reactive devices such as STATCOMs or SVCs can be employed to expand reactive capability. However, it is unclear what the power factor requirement refers to explicitly with respect to power factor capability at active power outputs other than nominal. It is assumed that the non-synchronous generation must meet the 0.95 leading to 0.95 lagging power factor capability using continuously-acting dynamic reactive resources for all real power outputs above 10% of nominal. This assumes a "box"-type reactive capability range. FERC should clarify this using a reactive capability diagram for non-synchronous generation plants, as measured at the Point of Interconnection (POI). In addition to the reactive capability curve, a complete specification should address the expected capabilities during off-nominal voltages. Non-synchronous generation may not, and should not necessarily, be required to provide full capability range at all operating voltages (e.g., a generator should not be required to provide full reactive power consumption when low voltage conditions are occurring at the POI). A reactive capability versus voltage characteristic would clearly address this issue and is recommended.
- **Minimum Output Level for Reactive Capability:** FERC's proposed permissive reactive power range for low real power output is technically justified and reasonable. A 10% minimum active power output level accounts for a dispersed power producing resource such as wind or solar not being able

to provide full capability range due to cycling individual units. At low output, some WTGs or PV inverters may be offline resulting in a reduction of reactive capability. Therefore, a 10% minimum output level accounts for this technology limitation while ensuring full dynamic reactive capability when attainable.

In addition to the topics that FERC sought comment on regarding the NOPR, NERC also addresses the following topics and provides observations worth noting regarding reactive power compensation and voltage control for non-synchronous generators:

- **Solar PV Consideration:** NERC agrees with including solar resources, as a non-synchronous form of generating resources, in the removal of exemption for reactive power capability in the *pro forma* SGIA and LGIA. However, NERC recommends directly addressing these resources in future considerations, as has been done with wind generation resources, particularly with the growing penetration of solar generation on the bulk power system and distribution systems. The technological performance capabilities are very similar between solar and modern wind turbine generators; hence, the requirements will likely be similar or the same.
- **Voltage Control vs. Power Factor Control:** NERC recommends FERC to clarify and consider the explicit requirement for non-synchronous generators to operate in a dynamic reactive power mode that maintains voltage to a scheduled value or within a defined range (i.e., voltage control mode). NERC Reliability Standard VAR-002 Requirement R1[1] specifies that each generator operate in "automatic voltage control mode (with its automatic voltage regulator (AVR) in service and controlling voltage) or in a different control mode as instructed by the [TOP]".
- **Dynamic versus Static Reactive Capability:** NERC strongly agrees that non-synchronous generation, along with synchronous generation, should be required to provide dynamic reactive power to the system in support of both voltage scheduling and contingency events that require transient voltage support. Switching of static resources for non-synchronous generation has caused coordination issues relating to maintaining system voltages with required ranges. Static resources also pose a challenge for an increasingly dynamic and variable bulk power system.
- **System Impact Study Considerations:** While the assessment of reactive capability requirements for non-synchronous generating resources have historically been assessed during the System Impact Study (SIS), the increasing penetration of these resources makes it a challenge to adequately assess the system's needs under a myriad of operating conditions. Therefore, NERC agrees with the proposed revision to explicitly require dynamic reactive power capability across a range of operating conditions for safe and reliable operation within defined voltage schedule (limits). This mitigates the risk of unplanned or unstudied operating conditions manifesting in a security risk to the bulk power system and ensures a fair and equitable requirement to all Generator Owners.
- **Voltage Ride Through Capability:** Voltage ride through (VRT) is not discussed in this FERC NOPR; however, NERC sees a possible inequity with respect to Low Voltage Ride Through (LVRT) requirements for BES synchronous and non-synchronous generators. On one hand, Appendix G of the LGIA, applicable only to wind plants, specifies that the Generation Facility must not disconnect

[1] See NERC Reliability Standard VAR-002-4. Available: http://www.nerc.com/_layouts/PrintStandard.aspx?standardnumber=VAR-002-4&title=Generator Operation for Maintaining Network Voltage Schedules&jurisdiction=United States

for voltages and times specified as per the Appendix. This requirement ensures that the Generation Facility remains connected for expected times, regardless of what may cause it to disconnect. On the other hand, NERC Reliability Standard PRC-024 applies to all BES generators, including wind and solar facilities that are BES Elements; however, it only prescribes that the generator voltage protective relays must be set according to the Standard and does not address auxiliary equipment that may trip the generator offline. NERC believes that FERC may want to consider a VRT requirement, similar to Appendix G, for all Generation Facilities including synchronous generators. NERC Event Analysis has experienced a number of events where the generating facility or unit was tripped due to auxiliary loads tripping, not generator protective relaying causing the disconnection.

- **Primary Frequency Response:** Frequency response (FR) is not discussed in this FERC NOPR; however, NERC believes that frequency response (as part of overall frequency support) is an Essential Reliability Service (ERS) to the bulk power system. While FERC has enabled the sale of primary frequency response service at market-based rates, NERC believes that frequency response should be mandated in the *pro forma* LGIA/SGIA similar to reactive power capability. As a subset of ERS, it is imperative that all resources have the capability to provide frequency response (and reactive support) when operating in a condition that facilitates frequency response (e.g., non-baseloaded). Provisions for market-based sale of primary frequency response provides a mechanism for entities to be compensated when reducing generation output for frequency response reasons; however, there are no requirements that ensure that all resources have the capability to provide frequency response. With a rapidly changing resource mix and bulk power system, ensuring frequency support is of utmost importance. NERC understands that newer non-synchronous generation, as well as synchronous generation, should all have the capability of providing frequency response and addressing this in the *pro forma* interconnection agreements is fair and equitable for all generation Facilities.

Overview

On November 19, 2015, the Federal Energy Regulatory Commission (FERC) issued a Notice of Proposed Rulemaking (NOPR)[2] [Docket No. RM16-1-000] "Proposal to Revise Standard Generator Interconnection Agreements", which proposes to "eliminate the exemptions for wind generators from the requirement to provide reactive power." FERC's proposal will revise the *pro forma* Large Generator Interconnection Agreement (LGIA) and Small Generator Interconnection Agreement (SGIA). The resulting outcome of this removal would require all newly interconnecting generators (new generators seeking interconnection and existing non-synchronous generators making upgrades to their facilities that require a new interconnection request), both synchronous and non-synchronous, to provide reactive power as a condition of interconnection.

The following conditions are addressed in the FERC NOPR:

1. **Exemption Removal:** The exemption for wind generators from the requirement to provide reactive power will be removed, effectively "requiring all newly interconnecting generators…to provide reactive power."

[2] Available: https://www.ferc.gov/whats-new/comm-meet/2015/111915/E-3.pdf

2. **Real Power Output Lower Limit:** Requirement that "non-synchronous generators maintain the required power factor range only when the generator's real power output exceeds 10 percent of its nameplate capacity."
3. **Power Factor Requirement:** Requirement that non-synchronous generation also provide reactive power to maintain power factor within the range of 0.95 leading to 0.95 lagging "at continuous rated power output at the Point of Interconnection" using dynamic reactive power.
4. **Study Approach:** A System Impact Study (SIS) by the Transmission Planner will no longer be needed to justify whether each new wind (any non-synchronous generator) needs to provide reactive power.
5. **Fairness:** These modification to the LGIA/SGIA will ensure fairness and equitability between synchronous machines and non-synchronous generation sources, avoiding unduly discriminatory burden on synchronous generators to provide reactive power.

Exemption Considerations & Response to NOPR Proposed Revisions

Wind generators were exempt from the reactive power requirements set forth for conventional synchronous generators, as defined in the *pro forma* Small Generator Interconnection Agreement (SGIA) and Large Generator Interconnection Agreement (LGIA). FERC sought to avoid creating major obstacles to the development of wind generation when the Commission issued Order Nos. 2003, 661, and 2006. Around the time of 2005 when Order No. 661 was issued, wind turbine generators (WTGs[3]) being installed were mainly Type II and some Type III installations. Type I and II machines are a form of induction generator, with little capability to dynamically control power factor at the Point of Interconnection. On the other hand, Type III machines use power electronics to control the excitation of the machine and Type IV machines use a full power electronic interface between the machine and the electrical grid which enables control of power factor.

The Commission considered the current state of technology and costs, stating "improvements in technology" and "declining costs…in providing reactive power" make it "unduly discriminatory and preferential" to non-synchronous generators being exempt from providing this service. It also highlighted the concern that "exempting a class of generators from providing reactive power could create reliability issues if those generators represent a substantial amount of total [online] generation". As penetration levels of non-synchronous generation (primarily wind and solar) continue to increase, this would be a growing concern.

[3] Wind Turbine Types: Type I: Fixed-speed wind turbines; Type II: Variable-slip wind turbines; Type III: Doubly-fed induction generator (DFIG) wind turbines; Type IV: Full-converter wind turbines

NERC Position: NERC agrees that the current state of the art in non-synchronous generation technologies and declining costs of these technologies make it "unduly discriminatory" and "preferential" to non-synchronous generators. The ability to control the production and absorption of reactive power for the purposes of maintaining desired voltages is critical to the reliable and efficient operation of the bulk power system (BPS); NERC considers voltage control an Essential Reliability Service (ERS) to the BPS. Furthermore, increasing penetrations of non-synchronous generation that do not provide voltage support by dynamic reactive power control would be a reliability risk moving forward. NERC supports removing this exemption for all non-synchronous generators.

Power Factor Capability within +/- 0.95 Lead/Lag

Active power is the component of electrical power that does work on electrical loads, such as providing energy to light a lightbulb. Reactive Power is the component of electrical power used to sustain the electric and magnetic fields in a circuit, sustaining voltage to drive electrical loads. Apparent power is the product of the current and voltage of the circuit. Power factor of an AC electrical system is defined as the ratio of active power to apparent power in a circuit and is a dimensionless number bounded between -1 and 1. Low power factor results in more current required to drive a load, increasing losses for the same amount of useful (real) power transferred. Unity power factor is when all the current provided is doing real work on the system, defined as 1.0 or unity power factor. For example, reactive power for 10 MVA load with 0.95 lagging power factor would be 3.12 Mvar, as shown below:

$$S = 10\ MVA$$
$$pf = +0.95$$
$$P = 0.95(10\ MVA) = 9.5\ MW$$
$$Q = \sqrt{S^2 - P^2} = \sqrt{10^2 - 9.5^2} = 3.12\ Mvar$$

Negative power factor for a generator describes when the unit is underexcited, resulting in consumption of reactive power from the system. Positive power factor for a generator describes overexcited conditions, resulting in production of reactive power to the system. Acceptable limits of production and consumption are a function of both the safe operation of the electrical machine as well as the need to maintain acceptable voltages on the system. Capability for a generator to provide or consume within a given power factor range ensures 1) dynamic reactive power is available when needed, 2) reactive power consumption (and production) stays within reasonable limits, and 3) system voltages can be planned for.

Section 1.8.1 of the *pro forma* SGIA states that "[t]he Interconnection Customer shall design its Small Generating Facility to maintain a composite power delivery at continuous rated power output at the Point of Interconnection at a power factor within the range of 0.95 leading to 0.95 lagging, unless the Transmission Provider has established different requirements that apply to all similarly situated generators in the control area on a comparable basis. The requirements of this paragraph shall not apply to wind generators." The NOPR proposes to strike the last sentence relating to wind generators, requiring that non-synchronous generation provide dynamic reactive capability between the range of 0.95 leading to 0.95 lagging, similar to synchronous generation.

Review of WTGs and their capability determined that most modern WTGs can provide "full leading and lagging range over full power range" with "capability of reactive compensation with no wind", resulting in "no need for FACTS devices"[4]. Figure 1 shows the reactive power control range (red lines define boundary) for a 1.5 MW General Electric (GE) WTG, for ± 0.9 power factor. GE states that "WTG reactive capability [is] often sufficient to satisfy PF requirements at POI" and that "VAR capability reduced at low power due to units cycling off-line". A. Ellis, et al.[5], state that "both PV plants and inverter-based wind plants are technically capable of providing reactive capability at full kVA output" and that "[PV] inverter manufacturers have "de-rated" their inverters and now provide both a kW and kVA rating" to meet the reactive power requirements similar to wind plants. If the WTGs are incapable of providing dynamic reactive capability over the full range, necessary dynamic reactive capability can be supplemented with a Static VAR Compensator (SVC) or Static Synchronous Compensator (STATCOM).

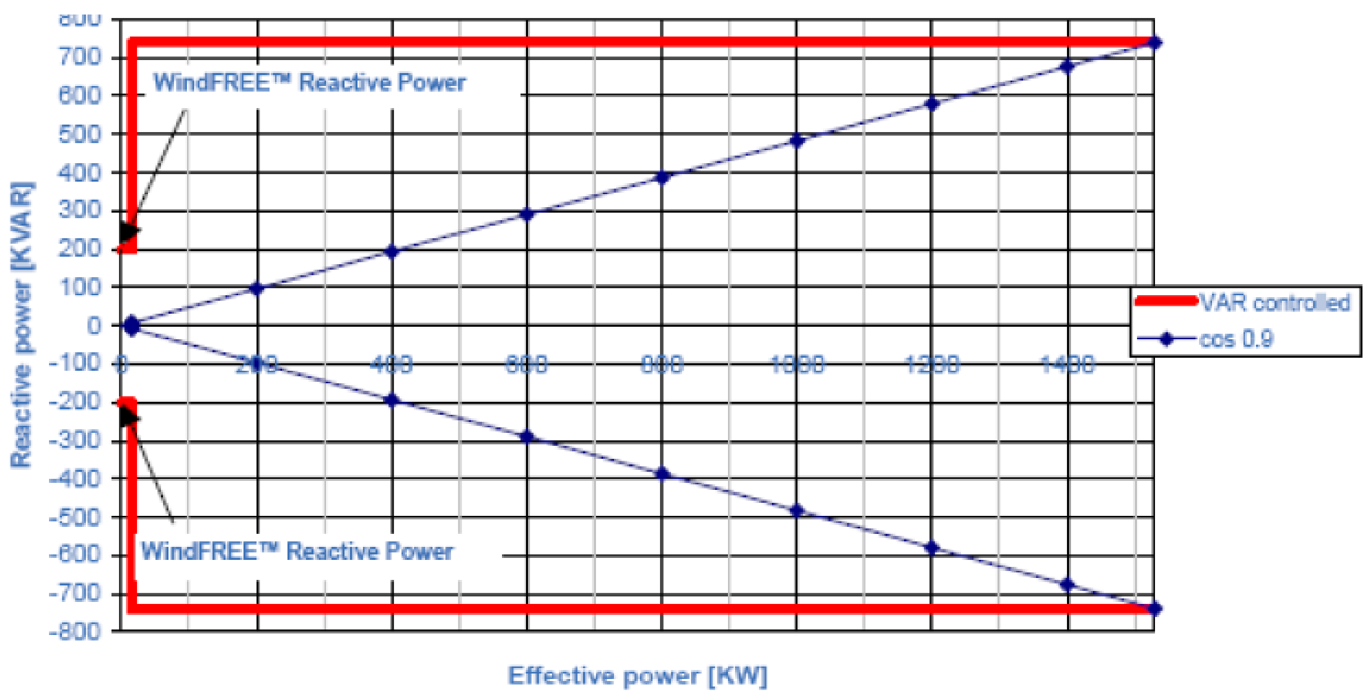

Figure 1: GE 1.5 MW WTG Reactive Power Capability

Figure 2 depicts the reactive capability for the required power factor range of 0.95 leading to 0.95 lagging. The non-synchronous generating facility must be able to provide reactive capability over full range of real power output down to 10% of rated power. The reactive capability bounds are determined by calculating the reactive power output for a ± 0.95 power factor, as shown by the green box in Figure 2. The blue lines in Figure 2 specify the reactive power production or consumption if operated in a constant power factor

[4] GE Energy Consulting, "CAISO Workshop on Reactive Power Requirements and Financial Compensation," CIASO. [Online]. Available: http://www.caiso.com/Documents/GEEnergyConsultingPresentation_ReactivePowerRequirements_FinancialCompensation_WorkingGroup.pdf.

[5] A. Ellis, et al., "Reactive Power Performance Requirements for Wind and Solar Plants," *2012 IEEE PES General Meeting*, pg. 1-8, 2012.

mode. NERC interprets the FERC NOPR to require this type of reactive capability, and agrees with this approach assuming that POI voltage is addressed as described below.

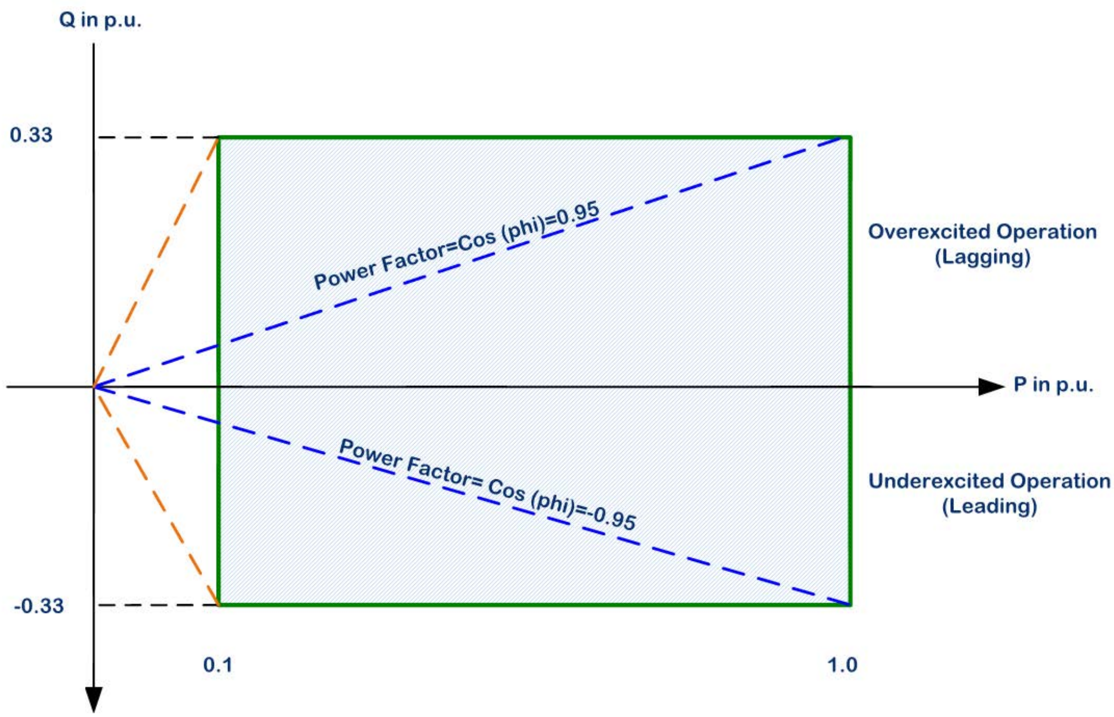

Figure 2: Proposed Non-Synchronous Generation Reactive Power Capability Curve

California ISO (CAISO) is proposing reactive power capability requirements for non-synchronous generating facilities as shown in Figure 3. CAISO is proposing continuous reactive power capability from 0.95 leading to 0.95 lagging power factor. However, CAISO is also proposing to require dynamic reactive capability within the range of 0.985 leading to 0.985 lagging, allowing for some of the reactive capability to be provided through static reactive resources. Furthermore, based on assumptions drawn from their proposed capability curve, CAISO is not proposing that the reactive power requirements defined at rated active power hold for all operating ranges. A “V” curve defined by ± 0.95 constant power factor is being used for defining the reactive capability limits. This is provided as a reference for alternative considerations; however, operation within the entire “V” curve range should consist of dynamic reactive capability.

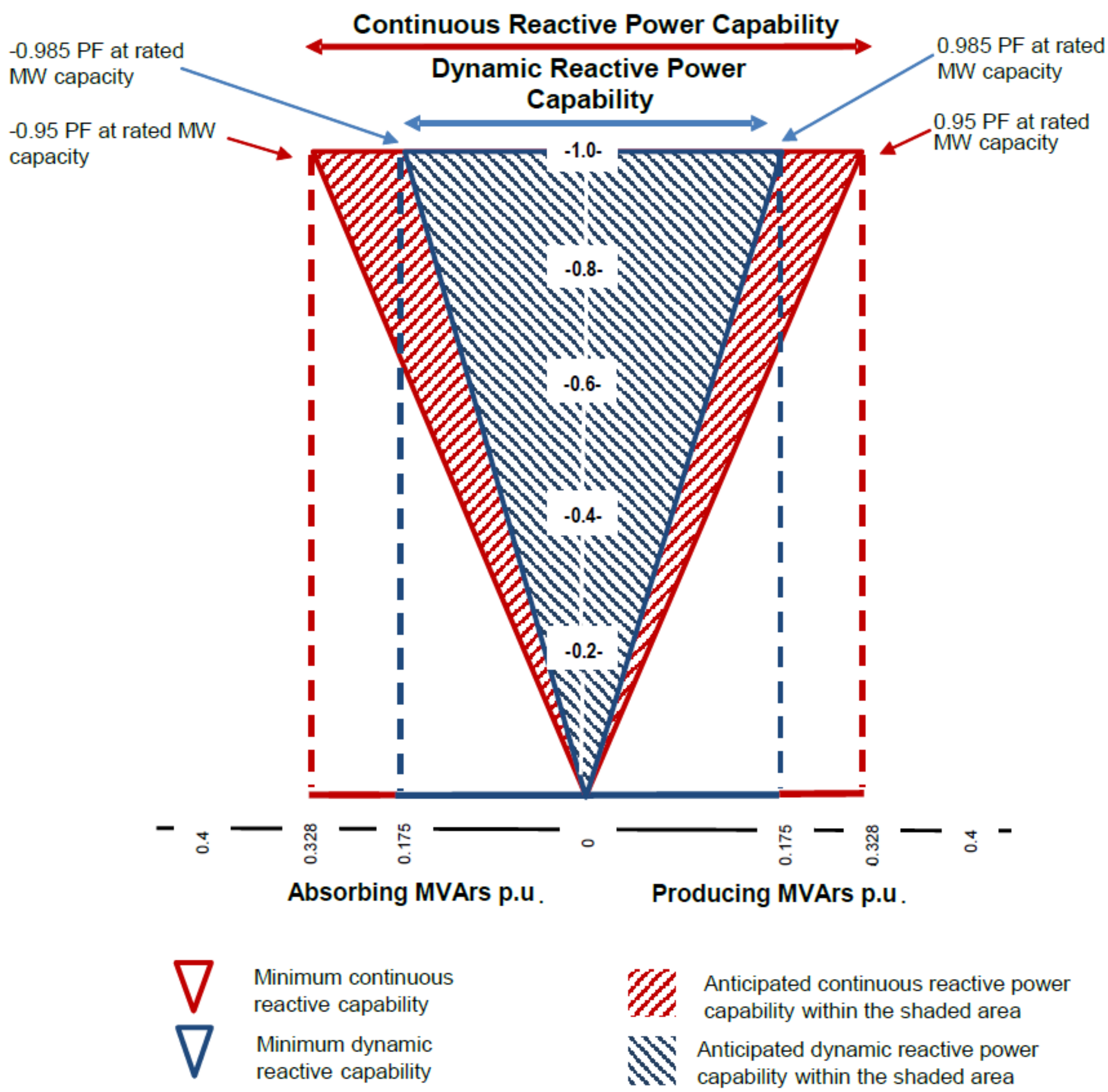

Figure 3: Proposed CAISO Reactive Capability Curve [Source: CAISO[6]]

The specification of 0.95 leading to 0.95 lagging power factor at full active power output proposed by FERC is slightly ambiguous because it does not address Point of Interconnection (POI) voltage. Terminal voltage limitations of the units can affect reactive power capability and therefore a reactive power versus voltage characteristic should be used in conjunction with the capability specification. Figure 4 shows an example of this Q vs. V capability curve. The non-synchronous power plant must have the capability to provide reactive power at 0.95 lagging when voltage is between 0.95 - 1.0 pu at the POI. Similarly, the non-synchronous power plant must have the capability to absorb reactive power at 0.95 leading when voltage is between 1.0 - 1.05 pu. Capability to provide reactive power decreases as voltage at the POI exceeds 1 pu; capability to absorb reactive power decreases as voltage at the POI drops below 1 pu. This is used as an illustration and may need to be adapted by Transmission Providers dependent on voltage schedule needs (e.g., based on POI voltage level).

[6] CAISO, "Reactive Power Requirements and Financial Compensation – Revised Straw Proposal," October 8, 2015.

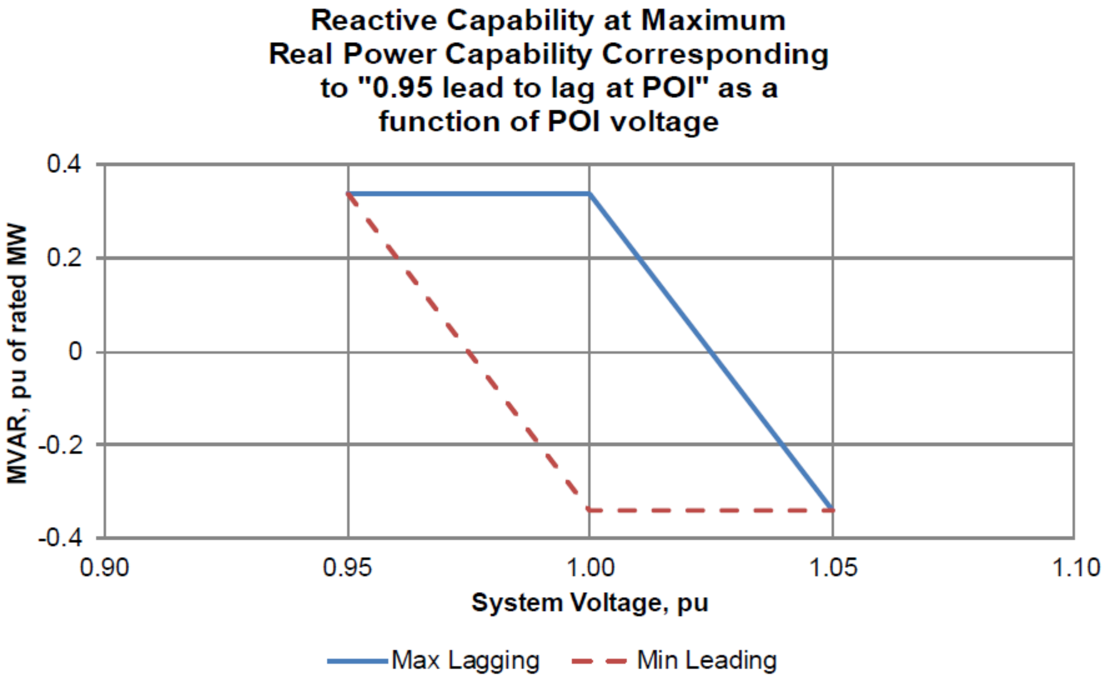

Figure 4: Reactive Capability Corresponding to POI Voltage [Source: CAISO[7]]

NERC Position: NERC agrees with the requirement for non-synchronous generation to comply with providing a "composite power delivery at continuous rated power output at the Point of Interconnection at a power factor within the range of 0.95 leading to 0.95 lagging, unless the Transmission Provider has established different requirements that apply to all similarly situated generators in the control area on a comparable basis." Review of inverter-based non-synchronous generation has identified that modern Wind Turbine Generator (WTG) technology can provide the full range of required power factor capability when online. For situations where the WTG itself cannot meet the full power factor requirements, dynamic reactive devices such as STATCOMs or SVCs can be employed to expand reactive capability. However, it is unclear what the power factor requirement refers to explicitly with respect to power factor capability at active power outputs other than nominal. It is assumed that the non-synchronous generation must meet the 0.95 leading to 0.95 lagging power factor capability using continuously-acting dynamic reactive resources for all real power outputs above 10% of nominal. This assumes a "box"-type reactive capability range. FERC should clarify this using a reactive capability diagram for non-synchronous generation plants, as measured at the Point of Interconnection (POI). In addition to the reactive capability curve, a complete specification should address the expected capabilities during off-nominal voltages. Non-synchronous generation may not, and should not necessarily, be required to provide full capability range at all operating voltages (e.g., a generator should not be required to provide full reactive power consumption when low voltage conditions are occurring at the POI). A reactive capability versus voltage characteristic would clearly address this issue and is recommended.

[7] CAISO, "Reactive Power Requirements and Financial Compensation – Revised Straw Proposal," October 8, 2015.

Minimum Real Power Output Level for Reactive Capability

FERC proposed to require "that newly interconnecting non-synchronous generators be required to design the generating facility to maintain the required power factor range only when the generator's real power output exceeds 10 percent of its nameplate capacity." Specifically, FERC proposes the following revision to section 9.6.1 of the pro forma LGIA and SGIA:

- ***LGIA:*** "Interconnection Customer shall design the Large Generating Facility to maintain a composite power delivery at continuous rated power output at the Point of Interconnection at a power factor within the range of 0.95 leading to 0.95 lagging, unless Transmission Provider has established different requirements that apply to all generators in the Control Area on a comparable basis. Non-synchronous generators shall only be required to maintain the above power factor when their output is above 10 percent of the Generating Facility Capacity."
- ***SGIA:*** "The Interconnection Customer shall design its Small Generating Facility to maintain a composite power delivery at continuous rated power output at the Point of Interconnection at a power factor within the range of 0.95 leading to 0.95 lagging, unless the Transmission Provider has established different requirements that apply to all similarly situated generators in the control area on a comparable basis. Non-synchronous generators shall only be required to maintain the above power factor when their output is above 10 percent of the generator nameplate capacity."

Figure 5 again depicts the reactive capability for the required power factor range of 0.95 leading to 0.95 lagging. The non-synchronous generating facility must be able to provide reactive capability over full range of real power output down to 10% of rated power.

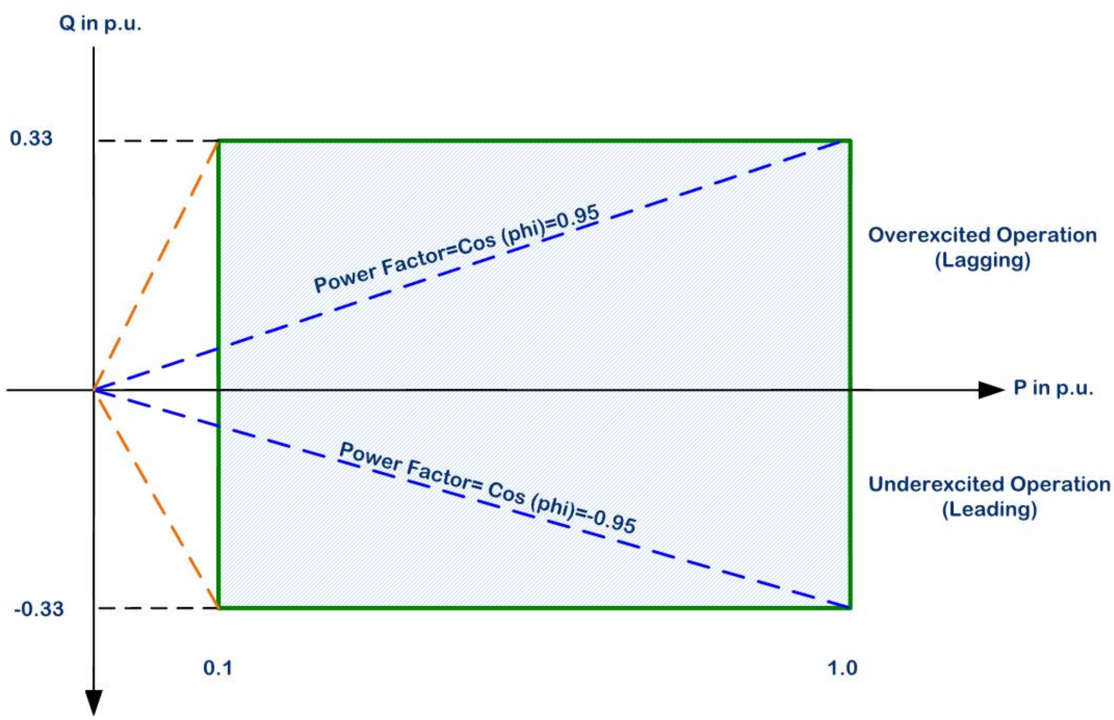

Figure 5: Proposed Non-Synchronous Generation Reactive Power Capability Curve

The preceding section gives examples of actual WTGs and their capabilities, and illustrates how the WTGs themselves can provide sufficient reactive power control; however, at very low output levels it is hard for the plant as a whole to control VARs because the WTGs are cycling between power production and offline. Since all or a large portion of the generators in a wind or solar plant may be offline during periods of low output, it is difficult to meet the full range of reactive capability at low real power output levels. Therefore, a permissive reactive power range (i.e., 10% of nominal real power rating) where the plant does not have to meet the reactive power capability envelope is technically justifiable and reasonable.

NERC Position: FERC's proposed permissive reactive power range for low real power output is technically justified and reasonable. A 10% minimum active power output level accounts for a dispersed power producing resource such as wind or solar not being able to provide full capability range due to cycling individual units. At low output, some WTGs or PV inverters may be offline resulting in a reduction of reactive capability. Therefore, a 10% minimum active power output level accounts for this technology limitation while ensuring full dynamic reactive capability when attainable.

Other Comments on FERC NOPR

The following sections describe additional considerations worth noting in regards to the FERC NOPR on proposed changes to the *pro forma* SGIA and LGIA related to reactive power capability. While FERC did not explicitly request comment on these topics, NERC Staff took the opportunity to document technical considerations related to the topic here.

Solar PV Considerations

The FERC NOPR addresses removing the exemption of wind generation from the *pro forma* SGIA and LGIA requirements related to reactive power capability. The proposed changes require that all non-synchronous generation comply with the requirements set forth including wind, solar, and other inverter-based generation. It is clear from the NOPR that FERC-jurisdictional solar power resources such as solar photovoltaic (PV) will also be subject to the requirements.

Solar power is rapidly increasing penetration levels in key locations such as California, North Carolina, and other states based on federal and state-level tax incentives that subsidize the cost of installing solar resources. Manufacturing costs of solar PV resources continue to decline, and coupled with the extension of federal tax credits to 2019 in the 2015 Spending Bill[8] recently passed by Congress, solar will continue to be a competitive renewable energy resource for the next few years. The incentive to continue rapid development and deployment of solar resources will continue to drive down manufacturing costs, potentially eliminating the need for incentives to sustain cost competitiveness.

As an emerging component of the overall generation mix, it is in the best interest of grid reliability and safety to be proactive about setting necessary and equitable requirements for all generating resources. The FERC NOPR implicitly applies the requirements for reactive capability to solar by requiring all non-synchronous generating resources to meet the requirements in the *pro forma* SGIA and LGIA. However, it

[8] http://www.ibtimes.com/congress-omnibus-spending-bill-2015-us-solar-shares-rise-key-tax-credit-extensions-2230508

seems appropriate to explicitly include solar in future considerations since the technology is very similar between modern wind and solar resources (particularly Type 4 wind turbine generators).

NERC Position: NERC agrees with including solar resources, as a non-synchronous form of generating resources, in the removal of exemption for reactive power capability in the *pro forma* SGIA and LGIA. However, NERC recommends directly addressing these resources in future considerations, as has been done with wind generation resources, particularly with the growing penetration of solar generation on the bulk power system and distribution systems. The technological capabilities are very similar between solar and modern wind turbine generators; hence, the requirements will likely be similar or the same.

Voltage Control vs. Power Factor Control

There is confusion around the language as written in the FERC NOPR. The proposed language, which NERC agrees with fundamentally, states that the Interconnection Customer must maintain "power factor within the range of 0.95 leading to 0.95 lagging". This, as written, does not specify how that power factor is maintained and the control strategies used to maintain that power factor. While NERC agrees that this should not be prescriptive, it does leave it open to interpretation with respect to voltage control and power factor control. Modern wind power plants and solar facilities may operate in a constant power factor mode (i.e., to maximize real power output by maintaining unity power factor) or operate in a voltage control mode holding a scheduled voltage at the Point of Interconnection (i.e., with a voltage droop characteristic).

In the NOPR, Section 2, it specifies that "this reactive power requirement requires dynamic reactive power from generators" and clarifies that "dynamic reactive power devices are characterized by faster acting and continuously variable voltage control capability."

What is unclear is what operating modes non-synchronous generation can operate in. Conventional synchronous generation is required to operate in a voltage control mode using a scheduled voltage set point defined by the Transmission Provider at the Point of Interconnection (e.g., high side of the generator step up (GSU) transformer). It is clear, especially with increasing penetration of non-synchronous generation, that these power plants should be required to:

1) Provide dynamic reactive power capability; and
2) Operate in voltage control mode to a scheduled voltage as defined by the Transmission Provider, unless another operating mode is acceptable to the Transmission Provider.

NERC Position: NERC recommends FERC to clarify and consider the explicit requirement for non-synchronous generators to operate in a dynamic reactive power mode that maintains voltage to a scheduled value or within a defined range (i.e., voltage control mode). The *pro forma* LGIA/SGIA set the requirement for Generation Facilities to be capable of +/- 0.95 power factor; however, NERC Reliability Standard VAR-002 sets the requirement on how the Generation Facilities are controlled.

Dynamic versus Static Reactive Capability

The FERC NOPR states that the existing *pro forma* SGIA and LGIA both require an interconnecting generator to maintain a given power factor range and that the reactive power requirements "requires dynamic reactive power from generators." The Commission proposes to eliminate the exemption of wind generators and require all interconnecting non-synchronous generation to "provide dynamic reactive power as a condition of interconnection." FERC also provides background of why this was not addressed in Order No. 661, but states in the NOPR that "based on technological advancements, the Commission no longer believes it is just and reasonable and not unduly discriminatory" to exempt wind or other non-synchronous generation.

Reactive power is an Essential Reliability Service (ERS) to the bulk power system for ensuring acceptable operating voltages and voltage stability. Dynamic reactive capability on the bulk power system is becoming increasingly necessary for a number of reasons. The increasing penetration of variable, intermittent resources such as wind and solar drives the need for these types of generating resources to provide this ERS. The variability of these resources is driving higher resolution scheduling and the need for a more flexible grid. Variability in transfers and online resources drives fluctuating voltage levels that must be managed with relatively fast acting resources. While static reactive resources such as fixed or mechanically switched capacitors and reactors have historically sufficed, dynamic reactive capability was provided by large synchronous machines and variability was limited. Today's power system and that of the future will see increasing variability, demanding dynamic reactive capability as an ERS to the bulk power system.

NERC Position: NERC strongly agrees that non-synchronous generation, along with synchronous generation, should be required to provide dynamic reactive power to the system in support of both voltage scheduling and contingency events that require transient voltage support. Switching of static resources for non-synchronous generation has caused coordination issues relating to maintaining system voltages with required ranges. Static resources also pose a challenge for an increasingly dynamic and variable bulk power system.

Removing System Impact Study Requirements

The Interconnection System Impact Study (SIS) is an "engineering study that evaluates the impact of the proposed interconnection on the safety and reliability of the Transmission Provider's Transmission System and, if applicable, an Affected System[9]." These studies include assessment of the system without modifications, any Adverse System Impacts identified, and system modifications to remedy the violations identified. These studies will generally include a steady-state powerflow assessment as well as dynamic assessments such as transient, voltage, and small signal stability.

Most commonly, these studies are performed under heavy loading conditions such as heavy summer and/or heavy winter as well as light load conditions such as spring or shoulder times. However, there is a clear differentiation between Planning studies and actual system conditions. While the system is planned

[9] FERC, "Large Generator Interconnection Agreement," Federal Energy Regulatory Commission, Washington, DC. [Online]. Available: http://www.ferc.gov/industries/electric/indus-act/gi/LGIA.pdf

under a certain set of assumptions, actual operating conditions can and do change drastically from the planned conditions. System topology changes due to planned or forced outages, changes in generation dispatch, and other ancillary impacts result in conditions that are not addressed or identified in the SIS results.

The variability of most non-synchronous generating resources such as wind and solar also poses another challenge for grid operators and planners. It is hard to assess beforehand how the variability of the resource(s) will affect the bulk power system. Particularly, local voltage control or stability issues can arise that go undetected in system studies. This is especially an issue for generating resources relying on static reactive capability from mechanically switched shunt capacitors or reactors. The coordination between the WTGs and plant-level controls, as well as other nearby generating plants, can pose a significant challenge to maintaining voltage schedules.

NERC Position: While the assessment of reactive capability requirements for non-synchronous generating resources have historically been assessed during the System Impact Study (SIS), the increasing penetration of these resources makes it a challenge to adequately assess the system's needs under a myriad of operating conditions. Therefore, NERC agrees with the proposed revision to explicitly require dynamic reactive power capability across a range of operating conditions for safe and reliable operation within defined voltage schedule (limits). This mitigates the risk of unplanned or unstudied operating conditions manifesting in a security risk to the bulk power system and ensures a fair and equitable requirement to all Generator Owners.

Low Voltage Ride Through

The FERC NOPR, discussed herein, does not directly address voltage ride through (VRT); however, NERC believes it is important to highlight key points regarding VRT for all generating resources. The application of Appendix G to wind generation and NERC Reliability Standard PRC-024 to BES generation of all types inherently creates a potential inequity in LVRT requirements for BES generation in terms of remaining online for grid disturbances.

FERC Order No. 661-A adopted standard procedures and technical requirements for interconnecting large wind plants in Appendix G. Low voltage ride-through (LVRT) capability was established for all wind Generation Facilities in Appendix G, specifying minimum times and voltage levels that the wind generator must "ride through" and remain connected to the system. This ensures continuity of the bulk power system wind generation resources to support reliability.

NERC Reliability Standard PRC-024 goes into effect July 1, 2016. The initial development of PRC-024 was very similar to the requirement set forth in Appendix G. The Standard was requiring that generator protective relays and auxiliary equipment could not disconnect the generator for prescribed voltage levels and times. The industry pushed back on the auxiliary equipment requirement and the Standard ended up as a "relay setting" standard for generator protective relaying that trips based on voltage. NERC Reliability Standard PRC-024 applies to all Bulk Electric System generators, including both synchronous and non-synchronous Generation Facilities that are BES Elements. However, it only prescribes that the generator voltage protective relays must be set according the Standard and does not address the potential for auxiliary equipment that may trip the generator offline. PRC-024 Requirement R2 states:

> “R2. Each Generator Owner that has generator voltage protective relaying activated to trip its applicable generating unit(s) shall set its protective relaying such that the generator voltage protective relaying does not trip the applicable generating unit(s) as a result of a voltage excursion (at the point of interconnection) caused by an event on the transmission system external to the generating plant that remains within the “no trip zone” of PRC-024 Attachment 2.4 If the Transmission Planner allows less stringent voltage relay settings than those required to meet PRC-024 Attachment 2, then the Generator Owner shall set its protective relaying within the voltage recovery characteristics of a location-specific Transmission Planner’s study. Requirement R2 is subject to the following exceptions: *[Violation Risk Factor: Medium] [Time Horizon: Long-term Planning]*
>
> - Generating unit(s) may trip in accordance with a Special Protection System (SPS) or Remedial Action Scheme (RAS).
> - Generating unit(s) may trip if clearing a system fault necessitates disconnecting (a) generating unit(s).
> - Generating unit(s) may trip by action of protective functions (such as out-of-step functions or loss-of-field functions) that operate due to an impending or actual loss of synchronism or, for asynchronous generating units, due to instability in power conversion control equipment.
> - Generating unit(s) may trip within a portion of the “no trip zone” of PRC-024 Attachment 2 for documented and communicated regulatory or equipment limitations in accordance with Requirement R3.

These requirements apply to all FERC-jurisdictional BES generating resources with voltage protective relays, and PRC-024 explicitly highlights the inclusion of “dispersed power producing resources identified through Inclusion I4 of the Bulk Electric System definition.” Attachment 2 of PRC-024 describes the required voltage levels and durations for voltage protective relaying on the generator, and is shown in Figure 6 and Table 1.

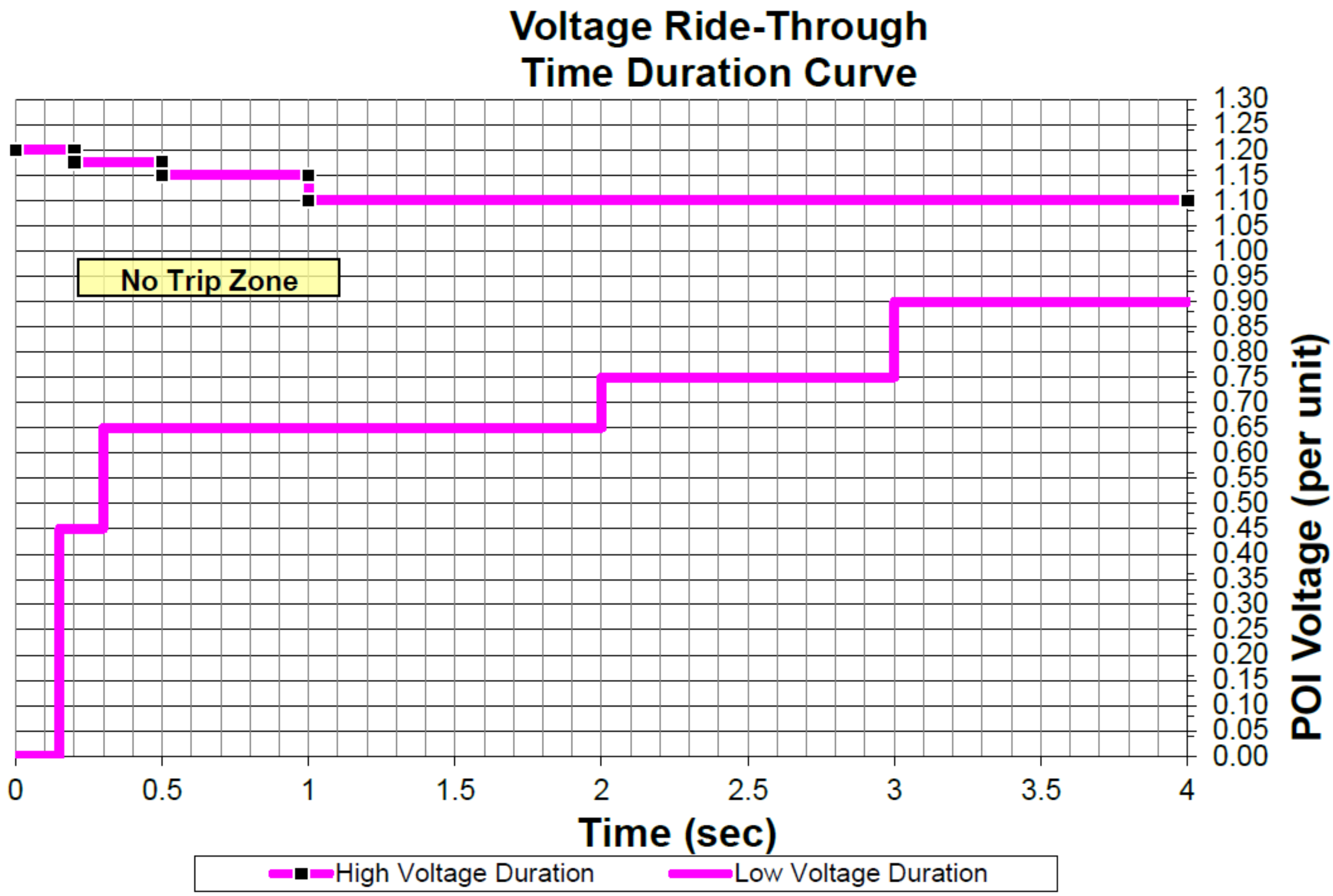

Figure 6: PRC-024 Low Voltage Ride Through Duration Curve

Table 1: PRC-024 Low Voltage Ride Through Duration

High Voltage Ride Through Duration		Low Voltage Ride Through Duration	
Voltage (pu)	**Time (sec)**	**Voltage (pu)**	**Time (sec)**
≥1.200	Instantaneous trip	<0.45	0.15
≥1.175	0.20	<0.65	0.30
≥1.15	0.50	<0.75	2.00
≥1.10	1.00	<0.90	3.00

NERC Event Analysis has experienced a number of such events where the generating facility or unit was tripped due to auxiliary loads tripping, not generator protective relaying causing the disconnection. Requirements by FERC, similar to those set forth in Appendix G, for both synchronous and non-synchronous Generation Facilities regarding LVRT would ensure continuity of the BES generation.

For distributed energy resources (DER) that are not FERC jurisdictional, IEEE Std. 1547[10] ("IEEE 1547") provides recommended practices for DER, including VRT recommendations. State interconnection standards and requirements for DER are generally consistent with IEEE standard, further supporting continuity of the grid at the distribution level. IEEE 1547-2003 and IEEE 1547a-2014 are approved standards; however, IEEE 1547a is undergoing a complete revision currently and the latest LVRT requirements that NERC Staff is aware of are reported in Table 2. For example, DER can disconnect at voltages below 45% of nominal at the point of common coupling after 0.16 seconds. Similarly, disconnection can occur after 2 seconds for voltages between 60-88% of nominal. These values are relatively consistent with PRC-024, and ensure the DER can ride through most normally cleared faults on the bulk system as well as distribution system.

Table 2: IEEE 1547a Low Voltage Ride Through Duration

Voltage Range in percent of the nominal voltage at the point of common coupling	Default Clearing Time in Seconds	Clearing Time Range in Seconds
V<45	0.16	0.16
45≤V≤60	1	1-11
60≤V≤88	2	2-21

In addition to specifying capability ranges, modern inverter-based generation is equipped with a Q priority feature that is designed to inject dynamic reactive power during abnormal voltage conditions. For instance, with the Q priority feature enabled, the inverter control system activates reactive current injection logic when the voltage dips below a pre-determined set-point (V_{dip}). Once the voltage has recovered ($> V_{dip}$), the inverter returns to steady-state operating mode. Enabling the Q priority feature in modern inverter-based generators can play an important role in minimizing the effects of delayed voltage recovery for severe contingencies.

To summarize, Appendix G applies to wind generation and NERC Reliability Standard applies to all BES generators. While Appendix G requires the Generation Facility to maintain connected for a given voltage and duration, PRC-024 only applies to generator protective relaying settings. These observations are consistent with the NERC report[11] developed regarding LVRT by the NERC Integration of Variable Generation Task Force (IVGTF). Therefore, FERC should consider a consistent requirement, similar to

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[10] IEEE Std. 1547a-2014. "IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems – Amendment 1". Institute of Electrical and Electronic Engineers. [Online]. Available: https://standards.ieee.org/findstds/standard/1547a-2014.html.

[11] NERC IVGTF, "Performance of Distributed Energy Resources During and After System Disturbance – Voltage and Frequency Ride-Through Requirements," NERC Report, December 2013. Online. Available: http://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/IVGTF17_PC_FinalDraft_December_clean.pdf

Appendix G, regarding LVRT for all types of generation including synchronous and non-synchronous generation.

NERC Position: Voltage ride through (VRT) is not discussed in this FERC NOPR; however, NERC sees a possible inequity with respect to Low Voltage Ride Through (LVRT) requirements for BES synchronous and non-synchronous generators. On one hand, Appendix G of the LGIA, applicable only to wind plants, specifies that the Generation Facility must not disconnect for voltages and times specified as per the Appendix. This requirement ensures that the Generation Facility remains connected for expected times, regardless of what may cause it to disconnect. On the other hand, NERC Reliability Standard PRC-024 applies to all BES generators, including wind and solar facilities that are BES Elements; however, it only prescribes that the generator voltage protective relays must be set according to the Standard and does not address auxiliary equipment that may trip the generator offline. NERC believes that FERC may want to consider a VRT requirement, similar to Appendix G, for all Generation Facilities including synchronous generators. NERC Event Analysis has experienced a number of events where the generating facility or unit was tripped due to auxiliary loads tripping, not generator protective relaying causing the disconnection.

Frequency Response

This FERC NOPR does not address frequency response or frequency support from non-synchronous generation; however, FERC has issued a Final Rule Order No. 819 [Docket No. RM15-2-000] on Third-Party Provision of Frequency Response Service permitting the sale of primary frequency response service at market-based rates by sellers with market-based rate authority for sales of energy and capacity. Similar to voltage control via reactive power support, NERC considers frequency support and primary frequency response capability to be an Essential Reliability Service (ERS) to the bulk power grid. Interconnections with growing amounts of non-synchronous generation are actively addressing frequency control to ensure adequate levels of reliability following major grid disturbances. NERC Reliability Standard BAL-003 defines an Interconnection Frequency Response Obligation (IFRO) and subsequent Balancing Authority Frequency Response Obligation (BA FROs) to preserve reliability and ensure the frequency nadir for the largest credible event stays above Under-Frequency Load Shedding (UFLS) levels.

The NERC Essential Reliability Services Task Force (ERSTF) Framework Report[12] addresses a number of frequency support aspects via its Measures:

- Measure 1: Synchronous Inertial Response at an Interconnection Level
- Measure 2: Initial Frequency Deviation Following Largest Contingency
- Measure 3: Synchronous Inertial Response at a BA Level
- Measure 4: Frequency Response

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[12] NERC, "Essential Reliability Services Task Force Measures Framework Report," Atlanta, GA, January 2016. Available: http://www.nerc.com/comm/Other/essntlrlbltysrvcstskfrcDL/ERSTF%20Framework%20Report%20-%20Final.pdf

These measures strive to track the performance of the interconnection and BAs in providing adequate levels of frequency response both at the inertial, primary, and secondary frequency response timeframes.

In addition to the ERSTF efforts to define Measures to be tracked moving forward, NERC has also been actively working with the industry to develop a Reliability Guideline on Primary Frequency Control[13]. The Reliability Guideline provides a strategy for primary frequency control during large frequency excursions as well as information for industry recommending governor deadband and droop settings that will potentially enable resources to provide better frequency response to the BES.

NERC Position: Frequency response (FR) is not discussed in this FERC NOPR; however, NERC believes that frequency response (as part of overall frequency support) is an Essential Reliability Service (ERS) to the bulk power system. While FERC has enabled the sale of primary frequency response service at market-based rates, NERC believes that frequency response should be mandated in the *pro forma* LGIA/SGIA similar to reactive power capability. As a subset of ERS, it is imperative that all resources have the capability to provide frequency response (and reactive support) when operating in a condition that facilitates frequency response (e.g., non-baseloaded). Provisions for market-based sale of primary frequency response provides a mechanism for entities to be compensated when reducing generation output for frequency response reasons; however, there are no requirements that ensure that all resources have the capability to provide frequency response. With a rapidly changing resource mix and bulk power system, ensuring frequency support is of utmost importance. NERC understands that newer non-synchronous generation, as well as synchronous generation, should all have the capability of providing frequency response and addressing this in the *pro forma* interconnection agreements is fair and equitable for all generation Facilities.

[13] NERC, "Reliability Guideline: Primary Frequency Control," Atlanta, GA, Dec 2015. Available: http://www.nerc.com/comm/OC/Reliability%20Guideline%20DL/Primary_Frequency_Control_final.pdf

Appendix A: Wind Turbine Generator Types

The following is a brief description of Wind Turbine Generator (WTG) types and how they are operated:

- **Type I – Fixed-Speed Wind Turbine:** squirrel-cage induction machine directly connected to the grid; very little variation in turbine rotor speed; no dynamic control of reactive power at WTG level, requiring additional reactive devices to compensate.
- **Type II – Variable-Slip Wind Turbine:** control the resistance in the rotor of the machine to allow for variable slip (speed) control up to approximately 10%; little control of reactive power at WTG level, requiring additional reactive devices to compensate.
- **Type III – Doubly Fed Induction Generator (DFIG) Wind Turbine:** back-to-back AC/DC/AC power converter for flux-vector control of rotor currents, allowing decoupled control of active and reactive power output; maximized wind power extraction and lower mechanical stress; lower-rated converter ratings since converter only applies to rotor circuit; WTG can provide dynamic reactive control through rotor current at acceptable levels of power factor (i.e., ± 0.95 lead/lag).
- **Type IV – Full Converter Wind Turbine:** back-to-back AC/DC/AC power converter directly in-line with stator circuit of WTG; synchronous or induction machine design; independent active and reactive power control; WTG speed variable and compensated to nominal frequency in converter.

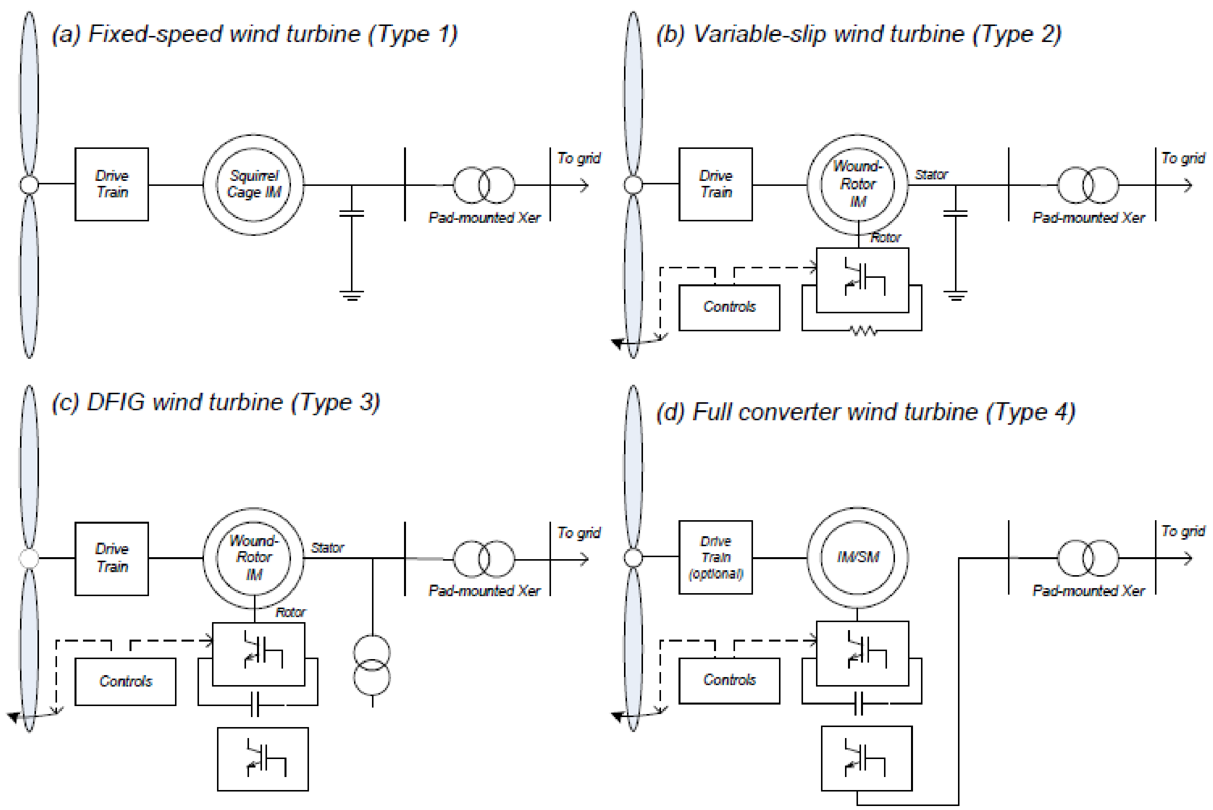

Figure 7: Wind Turbine Generator Types [Source: NREL[14]]

[14] M. Singh, S. Santoso, "Dynamic Models for Wind Turbines and Wind Power Plants," National Renewable Energy Laboratory, Golden, CO, October 2011. [Online]. Available: http://www.nrel.gov/docs/fy12osti/52780.pdf.