Interim
Interconnection Requirements for Large Generator Facilities Review Initiative

Draft Final Straw Proposal

April 20, 2010

1. Background

The broad acceptance of policies advocating greater reliance on variable renewable generation to meet California's electricity demand implicitly rests, in significant part, upon an assumption that the reliability of the power system will be maintained. The NERC Integration of Variable Generation Task Force (IVGTF)[1] report[2] recognized that "[t]o accommodate higher penetration of variable generation, changes will be required to traditional methods used by system planners and operators in order to maintain the reliability of the bulk power system on an ongoing basis. Making these significant changes will be challenging for the industry, however they will be needed to continue maintaining bulk power system reliability while integrating large amounts of variable generation." Among the necessary changes identified by NERC and other entities are those that focus on interconnection requirements, or the basic design features and capabilities, applicable to variable generation.

Consistent with NERC's guidance, the California Independent System Operator Corporation (ISO) has commenced this initiative to promote the continued reliability of the ISO controlled grid by refining a limited number of interconnection requirements for new large generating facilities, i.e., those facilities greater than 20 MW. The scope and summary of the ISO's proposal is set forth in the next section below. Although the ISO seeks to adopt uniform requirements, whenever possible and appropriate, that apply to all generation technologies, the expedited nature of this effort compels narrowing the focus to asynchronous generation technologies in large part. In so doing, the ISO recognizes the need to account for the special operating characteristics of some variable generation technologies.

The ISO further recognizes the value to Original Equipment Manufacturers (OEMs) and variable generation developers of uniform requirements not only within the ISO, but regionally and nationally. The ISO intends to coordinate with NERC and WECC processes and, more importantly, has taken efforts to ensure the convergence of any requirements developed through this initiative and standards ultimately approved by those entities.

The ISO believes this initiative must proceed and conclude expeditiously. The ISO has over 17,000 MW of variable generation capacity in the "serial group" and "transition cluster" portions of its interconnection queue.[3] For the projects representing this capacity, the interconnection studies are complete, nearing completion or are being accelerated to finish by June 2010 in order to accommodate potential funding opportunities under the American Reinvestment and Recovery Act.

[1] In December 2007, NERC's Planning and Operating Committees created the Integration of Variable Generation Task Force and charged it with preparing a report to identify; 1) technical considerations for integrating variable resources into the bulk power system, and 2) specific recommendations for practices and requirements, including reliability standards that cover the long-term planning, operations planning, and real-time operating timeframes.
[2] NERC IVGTF report is located at: http://www.nerc.com/docs/pc/ivgtf/IVGTF_Report_041609.pdf.
[3] The serial group has over 12,000 MW of renewable resource capacity, while the transition cluster has over 9,000 MW of renewable resource capacity.

The ISO intends to work with the stakeholders to finalize any refinements to the interconnection requirements by the end of April 2010, seek Board of Governors approval in May 2010, and file any necessary changes to the Large Generator Interconnection Agreement (LGIA) with the Commission thereafter. The specific schedule is as follows:

Date	Activity
February 19, 2010	Stakeholder Call to introduce this initiative
April 1, 2010	Stakeholder Meeting to present Straw Proposal
April 8, 2010	Receive Stakeholder Comments
April 20, 2010	Publish draft Final Straw Proposal
April 27, 2010	Stakeholder Conference Call
April 30, 2010	Stakeholder Comments on draft Final Straw Proposal
May 17-18, 2010	Seek Board of Governor Approval of Policy
May 24, 2010	Publish Proposed Changes to LGIA, as necessary
May 31, 2010	Stakeholder Conference Call on LGIA Changes
June 2010	File LGIA/Tariff Changes at FERC

As noted above, given the accelerated timeline for this initiative, the ISO acknowledges the need to restrict its scope. In this regard, the intent is to focus narrowly on the capabilities of the generating facilities and equipment specifications. The precise manner in which some of these capabilities may be used will be left for future phases of this initiative. This first phase of the initiative is to consider changes solely to the LGIA. If changes to other market rules outside the LGIA are necessary for implementation, then such changes are outside the scope of this phase.

An example relates to requirements surrounding generation power management. The ISO currently seeks to ensure that variable generators design their facilities to include the capability of controlling their output – a capability common to many systems with significant variable generation and consistent with existing ISO Participating Generator obligations.[4] How and when this capability may be used will be explored fully in subsequent stakeholder processes. The ISO does not intend to employ any active power control capabilities addressed in this straw proposal until after a stakeholder process has resulted in identified market rules and procedures.

Until the final rules on the application of generation power management are finalized in a subsequent phase(s) of the initiative, some uncertainty over their impact on resource production levels will exist. The ISO is aware that this uncertainty has the potential to affect project financing and must be mitigated. Accordingly, one of the objectives of the stakeholder process has been to address this issue and other commercial sensitivities, such as accounting for the effect of existing power purchase agreements, existing equipment purchases, and the timing of long-lead time equipment procurement and

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[4] See, e.g., Bonneville Power Administration, Dispatch Standing Order 216 [http://www.transmission.bpa.gov/operations/wind_operations/docs/DSO216_Phase_II_Summary_10-13-09.pdf]; New York ISO, 127 FERC ¶ 61,130 (2009); ISO-NE, Technical Requirements for Wind Generation Interconnection and Integration [Alberta Electric System Operator, The existing CAISO LGIA section 9.7.2 requires generators to interrupt or reduce delivery of electricity as needed for reliability and safety reasons.

equipment development. Foregoing a discussion of the capability requirements pending the outcome of new market rules, however, will not eliminate potential uncertainty, but it can unacceptably jeopardize future grid reliability, lead to blunt or sub-optimal grid solutions, or unnecessarily complicate the LGIA negotiation process.

2. Scope, Applicability, and Summary of Proposed Recommendations

A. The recommendations in this document are applicable to Large Generating Facilities.
B. While some of the recommendations in this proposal are consistent with requirements imposed on all types of generation facilities, the scope of this proposal is to clarify the requirements for variable energy resources (VERs) and within the category of VERs, some of the recommendations apply only to those VERs that use inverters or other types of asynchronous generators.
C. Recommendations regarding market policies and operational procedures are beyond the scope of this initiative.
D. The recommendations are not intended to be applied retroactively to any interconnection project with an executed LGIA or that has been tendered an LGIA prior to adoption of any recommendations by the ISO Board of Governors. Moreover, as set forth below, the ISO proposes to exempt certain interconnection projects on the basis of a demonstrated significant commitment to procure equipment incompatible with any of the recommendations. Other potential grounds for exemption have been considered, but not adopted. These grounds related to certain commercial circumstances, including, but not limited to, the execution of a power purchase agreement that does not permit recovery of incremental costs resulting from compliance with the revised standards or an outstanding application for benefits under the American Reinvestment and Recovery Act. The justification for the exemption criteria associated with each recommended requirement is discussed more fully below.

The table below summarizes and compares present requirements with those proposed herein:

Requirement	What is in place today?	What is the proposal?
1) Power factor requirement	• Article 9.6.1 of LGIA establishes power factor requirement for all generators except wind as 0.9 lag/0.95 lead, measured at the generator terminals. • Appendix H of LGIA establishes power factor requirement for wind generators to be 0.95 lag/0.95 lead, measured at point of interconnection (POI).	• Maintain existing power factor requirement for synchronous generators as 0.9 lag/0.95 lead measured at the generator terminals • Recommend that power factor requirements for asynchronous generators (e.g. asynchronous wind generators, solar PV, Stirling engines) be 0.95 lag/lead, measured at POI.

Requirement	What is in place today?	What is the proposal?
	• Appendix H of LGIA provides that the system impact study (SIS) submitted by an interconnection customer must justify the need for power factor requirements. • There is a discrepancy between ISO tariff section 8.2.33 and Article 9.6.1 of the LGIA about the measurement point for power factor requirements .	• Establish the asynchronous power factor requirement as a default, rather than on a study-by-study basis. • Eliminates discrepancy between the ISO tariff and LGIA.
2) Voltage Regulation Requirements	• Article 9.6.2 of LGIA establishes the requirement for all" generators to maintain Voltage Schedules.	• Establish the voltage requirement to install an automatic voltage control system to regulate voltage at the POI, within the reactive capability of the generator facility.
3) Voltage and Frequency ride-through requirements	• Currently the only voltage ride through requirement in the ISO LGIA (Appendix H) is Low Voltage Ride through requirement for wind generators. • Article 9.7.3 of LGIA establishes the need for Interconnection Customer to design High & Low Frequency ride through, as required by Applicable Reliability Council (WECC). WECC's frequency-ride through requirements are included in WECC Under frequency Load Shedding Relay Application Guide.	• Extend Order No. 661-A low voltage ride through requirements to all VERs. • Require all VERs to comply with the existing WECC frequency ride through requirements.
4) Generator Power Management Requirements	• Active Power Management -ISO tariff sections 4.6.1.1, 7.1.3, 7.6.1, and 7/7.2.3 require all generating facilities with Participating Generator Agreements to operate such that the ISO can control their output under both normal and emergency conditions. • Ramp Rate Limits and Control – Currently, there is no reference to the need for ramp rate	• Require all VERs to install control systems that provide for active power management, including the capability to limit ramp rates and respond to <u>over</u> frequency conditions. • Require ramp rates controls that allow for a range of 5% and 20% of rated capacity per

Requirement	What is in place today?	What is the proposal?
	limit/control in ISO tariff. Conventional fuel source machines typically have "gradual" ramp rates, whereas VER plants could have very "steep" ramp rates, which could cause reliability issues in accommodating ramps. • Frequency Response – WECC MORC criteria require all synchronous machines to design a 5% droop setting to provide over-frequency & under-frequency governor response. Currently there is no requirement for VERs to provide any frequency response.	minute, with a default setting of 10%. • Extend WECC MORC 5% droop criteria to all VERs to respond to over frequency grid conditions.
5) Interconnection Application Data	• No requirement exists for submitting standard study models for LGIP studies.	• Require use of standard study models, if available.
6) Power System Stabilizers Requirement	• Article 5.4 of ISO LGIA requires power system stabilizers for all generators except Induction type wind plants.	• Create an exception for all asynchronous generators, including induction type wind plants and asynchronous solar plants.

3. Recommendations for Interconnection Standard Enhancements

3.1. Power Factor Requirement for asynchronous VER plants

The ISO proposes to require asynchronous VERs to have the capability of providing reactive power output within 0.95 lag to 0.95 lead as measured at the Point of Interconnection (POI). This requirement ensures the VER provides sufficient reactive power to maintain a specified voltage schedule in accordance with the ISO Tariff.

This 0.95 lag to 0.95 lead design recommendation is consistent with the capabilities already imposed on wind facilities under Appendix H of the LGIA pursuant to FERC Order No. 661-A. However, the ISO proposes the following key revisions related to this recommendation:

(a) The power factor requirements (0.95 lag to 0.95 lead) shall apply to all asynchronous VERs.
(b) The requirement will apply without the need to perform an interconnection study.

The ISO believes that extending the existing Order No. 661-A beyond wind facilities to solar photovoltaic generators, or other asynchronous technologies, is appropriate given the similarity in power converter systems used by such technologies. Asynchronous VERs, including wind, utilize inverter based technology to deliver power to the ISO grid in a synchronous manner. Also, both wind and solar photovoltaic facilities consist of multiple generating units. The extension of Order No. 661-A from wind to all VERs is a logical progression.

This requirement will not apply to any asynchronous generating facility that has an executed LGIA or has been tendered an LGIA as of the date this proposal is approved by the ISO Board of Governors. In addition, the requirement will not extend to any wind facility in the "serial group," without an LGIA or tendered LGIA, to the extent it was not required by a completed system impact study to provide 0.95 lead/lag power factor. Further, to the extent an asynchronous generating facility has executed an LGIA that provides for the existing 0.90 lag and 0.95 lead requirement that is applicable to synchronous machines, the interconnection customer may inform the ISO that it elects to comply with the revised requirement.

The reactive power sources needed to comply with this design requirement can be provided by: (1) the inverters associated with the asynchronous generation, (2) switched or fixed capacitors, (3) solid state devices (such as a STATCOM), or (4) a combination of these sources. Capacitors have been used extensively for many years to provide reactive power support to the power system. Capacitors are readily available and the application to the power grid is well understood by power system engineers. As such, applying the requirement is not expected to result in material engineering changes by the developer, delays in permitting, or the need to delay or redo any existing ISO interconnection study. Nor does the ISO believe that the presence of pre-existing power purchase agreement justifies an exemption. Notwithstanding the outcome of *Nevada Power Company,* FERC Docket No. ER10-508-000 (Feb. 10, 2010), solar facilities were required under the ISO Tariff to meet the existing power factor requirement and wind facilities without a completed system impact study or Phase II cluster interconnection study remained potentially subject to a power factor requirement under Order No. 661-A. It follows that for projects in the foregoing situations, the power purchase agreement should have taken such potential costs into consideration.

The ISO is aware that Order 661-A and *Nevada Power Company* place the burden on the transmission operator to establish the need for a power factor requirement. The ISO's 2007 Integration of Renewable Resources study, based on transient and post-transient analyses, concluded that "[a]ll new wind generation units must have the capability to meet the WECC requirements of ± 0.95 power factor. This reactive capability is essential for adequate voltage control." This conclusion as well as other subsequent analyses forms the basis of the ISO's recommendation to make the power factor requirement mandatory.

3.2 <u>Voltage Regulation Requirements</u>

Article 9.6.2 of LGIA establishes the requirement for an Interconnection Customer to maintain Voltage Schedules. This is applicable to "all" generators, conventional and VERs. In order to reliably operate the transmission system within an acceptable voltage range at the POI, the ISO proposes that all new generators connecting to the ISO grid adhere to these requirements. The requirements below outline some specifics related to designing the voltage regulation mechanism:

3.2.1 Install an Automatic Voltage Control system so that the generating facility can help regulate the transmission voltage at the POI both under steady state and disturbance conditions, as per the voltage schedule provided.

3.2.2 All reactive power devices used to vary the generating facility's reactive power output should be under the control of the Automatic Voltage Control system.

3.2.3 Coordinate with the Participating Transmission Owner (PTO) and the ISO for voltage schedule requirements at the POI.

3.2.4 The Automatic Voltage Control system will normally be required to regulate the voltage at the POI. However, in some circumstances, it may be more efficient to regulate the voltage at a point on the generator's side of the POI. This deviation will be acceptable to the ISO if approved by the PTO. Note: regulating voltage to a point other than the POI will not change the power factor requirements, i.e. the VER is still required to have sufficient reactive capability to maintain a 0.95 lag / lead power factor at the POI.

Each generation facility should design their systems so they can operate in either a voltage control mode or a power factor control mode. Based on the voltage schedule or power factor set point provided, the generation facility should be able to produce / absorb VARs in such a fashion as to meet the desired voltage / power factor setting at the POI. The normal mode of operation for generators is voltage control mode.

3.3 Ride-through Capability Requirements

In order to maintain reliability of the grid, it is critical that all new VERs be designed with fault ride-through capability. The ISO recognizes that it is critical for conventional generators to also have ride-through capability. However, the experience with existing conventional generation technology indicates that the need to establish an expedited standard is unnecessary. Accordingly, the requirement set forth herein applies only to asynchronous VERs with the expectation that solar thermal technology relying on conventional steam turbines will behave similarly to existing synchronous generation using equivalent technology. The ride-through capabilities addressed are (a) low voltage ride-through and (b) high and low frequency ride-through. As more fully discussed below, the ISO is no longer pursuing a high voltage ride-through requirement as part of the package going to the board in May 2010.

3.3.1 Reliability need for voltage ride-through capability

The interconnection of new generators should not introduce adverse operating impacts to the existing transmission system. Sympathetic tripping of wind plants and solar facilities is a known issue for faults near generating stations. Immediately after a fault occurs, the voltage will typically collapse on the faulted phase or phases. Immediately after the fault is cleared, the system voltage may experience a transient high voltage condition.

Typically most transmission system faults will be cleared within several cycles. However, if new generation facilities are not designed with ride-through capability to withstand the temporary low and high voltage conditions during the fault inception and clearing periods, then generation facilities will trip and stay offline even after the fault is cleared. The result is that generation may be lost for faults on the transmission system, even if the fault was temporary and successfully cleared.

High and low voltage ride-through capability will ensure that generators stay in service and connected to the grid during transient voltage conditions during system fault inception and clearing. WECC policy states that a control area operator should be able to withstand the loss of the largest generator by procuring sufficient spinning reserves. One consequence of regularly losing all or part of the generation due to sympathetic tripping from the outage of transmission lines or other generators is the adverse impact on control area performance. A fault that trips a nearby generation unit plus a significant amount of wind or solar generation (via sympathetic tripping) would result in a more severe system imbalance on the control area. This could potentially increase the magnitude of the largest single contingency, which has both reliability and financial implications.

ISO's discussions with several VER solar PV project developers indicate that, while not required, most utility scale generation projects utilize inverters that have controls typically designed for small scale distributed energy resources of 10 MVA or less. These inverters are designed to meet codes and standards per UL 1741 and IEEE 1547. The IEEE 1547 standard prescribes certain voltage and frequency trip settings, which are intended to trip the generation plant off-line rapidly after the transient voltage and/or frequency condition is detected. Also, once the generation plant is tripped off-line, it is required to stay off-line for five minutes after the fault. Conformance with IEEE 1547 presents a fundamental conflict with the ISO proposal. While the voltage and frequency ride-through capabilities are needed from generation plants so the plant can stay connected to the grid, the default voltage and frequency settings for inverters are such that the plant trips off-line shortly after the fault.

The impact of using IEEE 1547 standard control settings generation projects was analyzed in a recent IEEE paper[5], which concluded:

"[W]ith substantial PV generation that is compliant with IEEE 1547, system reliability is considerably reduced because of the extensive loss of PV generation during transmission faults. Adding low-voltage ride-through capability to PV systems improves the reliability of transmission systems with high-penetration PV."

3.3.2 Reliability need for frequency ride-through capability

The frequency on the power system is related to the amount of load and generation that are connected. When the load and generation are precisely balanced, the frequency will

[5] Bebic, J.;Walling, R.; O'Brien, K.; Kroposki, B.; Power and Energy Magazine, IEEE; Volume: 7 Issue:3
Page(s): 45 – 54; 02 May 2009

be 60 Hz. In the event that generation is lost through an unplanned or forced outage (e.g., a generating unit trips off line), the frequency will deviate below the nominal of 60 Hz. Immediately following the disturbance, the governors on the remaining generation units will adjust to attempt to arrest the frequency decline. It may be necessary for the AGC to make adjustments to bring the system frequency back to 60 Hz. During this transition time, it is essential for the system generators to remain on line. If additional generators trip during the transition, the system frequency will continue to deteriorate, and frequency restoration will be more difficult.

3.3.3 Present ride-through capability standards and revision activities

3.3.3.1 Voltage ride-through capability standards

Presently, there is one voltage ride-through standard. FERC Order No. 661-A describes the low voltage ride-through standard for wind generators. The requirements for this standard are in Appendix H of the ISO LGIA. Low voltage ride-through standards for all generators are also in place in Germany (per German MV Grid Code), Canada and several other countries. Within the United States, a regional voltage ride-through standard is under development - NERC PRC-024-1. NERC PRC-024-1 proposes a more extensive low voltage ride-through capability than does Order No. 661-A. In addition, PRC-024-1 proposes a high voltage ride-through capability. The details of this standard development activity are outlined below.

NERC-PRC-024-1 "is part of NERC's "Project 2007-09: Generator Verification". The intent of this standard is to establish technology-neutral requirements for all generators concerning voltage and frequency events. Requirements are currently being drafted for high/low voltage and high/low frequency ride-through capabilities. While the standard is still in draft format, discussions with the NERC team working on this standard indicate the requirements set forth in the second draft version of this standard are expected to stay generally intact for the future versions.

More information for this NERC activity and Draft 1 of NERC PRC-024-1 can be found at the following website:

http://www.nerc.com/filez/standards/Generator-Verification-Project-2007-09.html

The ISO expects NERC to publish Draft 2 of NERC PRC-024-1 on this website sometime in April/May 2010 timeframe. Various members within the WECC Reliability Council have been participating in development of NERC PRC-024-1. Prior to engaging with NERC staff on development of the standard, several member entities from WECC performed extensive analysis in developing WECC's voltage ride-through criteria.

NERC has incorporated most of WECC's work in developing voltage ride-through criteria.

Table 1 below lists high/low voltage limit and time requirements, as currently prescribed by the Draft 1 of NERC PRC-024-1.

Table 1: NERC PRC-024-1 Voltage Ride-through Performance Requirement

HVRT DURATION		LVRT DURATION	
Time (Sec)	Voltage (p.u.)	Time (Sec)	Voltage (p.u.)
0.20	1.200	0.15	0.000
0.50	1.175	0.30	0.450
1.00	1.150	2.00	0.650
4.00	1.100	3.00	0.750
		4.00	0.900

3.3.3.2 Frequency ride through standards

Article 9.7.3 of LGIA establishes the need for Interconnection Customer to design high & low frequency ride through, as required by WECC. WECC's frequency-ride through requirements are set forth in the WECC Off-Nominal Frequency Plan. The frequency ride-through requirements contained in the latest draft of NERC PRC-024-1 conflict with WECC's frequency ride-through requirements contained in the WECC Coordinated Off-Nominal Frequency Load Shedding and Restoration Plan (WECC ONF Plan). This document is located at:

http://www.wecc.biz/library/WECC%20Documents/Miscellaneous%20Operating%20and%20Planning%20Policies%20and%20Procedures/Off%20Nominal%20Frequency.pdf

The ride-through requirements for generators are also discussed in the WECC Under-frequency Load Shedding Relay Application Guide. The URL to this Guide appears below.

http://www.wecc.biz/committees/StandingCommittees/OC/TOS/RWG/Shared%20Documents/UFLS%20Relay%20Application%20Guide.pdf

The frequency ride-through requirements are listed in Table 1 of "Reference D: WECC ONF, Apr. 1, 2005" within this document. Table 2 below lists under/over frequency limits and WECC minimum times as per the WECC UF Load Shedding Relay Application Guide.

Table 2: WECC Generator Off-Nominal Frequency Performance Requirement

Under-frequency Limit	Over-frequency Limit	WECC Minimum Time
> 59.4 Hz	60 Hz to < 60.6 Hz	N/A (continuous operation)
≤ 59.4 Hz	≥60.6 Hz	3 minutes
≤ 58.4 Hz	≥61.6 Hz	30 seconds
≤ 57.8 Hz	-	7.5 seconds
≤ 57.3 Hz	-	45 cycles
≤ 57 Hz	>61.7 Hz	Instantaneous trip

3.3.4 Recommendations regarding ride-through capability requirements

Based on the foregoing, the ISO recommends:

3.3.4.1 Voltage ride-through capability:

The ISO proposes to extend the low voltage ride through requirement in Order No. 661-A to all asynchronous VERs. This will place wind and solar photovoltaic resources on an even level.

3.3.4.2 Frequency ride-through capability:

ISO recommends that new generation facilities comply with the off-nominal frequency requirements as per WECC UF Load Shedding Relay Application Guide. This plan addresses the performance of generation during frequency transients, and all WECC members are required to comply with this Guide. This recommendation to follow the WECC frequency ride-through requirement is consistent with CAISO LGIA Section 9.7.3. The purpose of this recommendation is to re-iterate that all new generators, including all VERs, need to comply with this requirement.

3.3.5 Exemptions and transition periods

By electing to extend the Order No. 661-A standard for low voltage ride-through, the need for significant exemptions and transition periods has been obviated. Multiple OEMs, including those for solar photovoltaic facilities, are capable of providing equipment that can comply with Order No. 661-A. As such, no transition period is included in the recommendation. However, consistent with prior requirements, asynchronous VERs, not already subject to Order No. 661-A, that have executed LGIAs or tendered LGIAs will not be required to comply with the proposed low voltage ride-through requirement. Similarly, asynchronous VERs that can demonstrate the significant financial commitment to procure equipment incompatible with this requirement by the date approved by the ISO Board of Governors will also not be subject to the requirement.

As noted above, NERC is currently in the process of developing an extension to the low voltage ride-through requirements specified in FERC 661-A, and is also considering the establishment of high voltage ride-through requirements. These efforts are based in part on a white paper developed by WECC. In its white paper, the WECC notes that both low and high voltage transients may exist during and immediately after faults are cleared. The ISO intends to monitor the performance of all resources during transient voltage events in the ISO controlled grid. In the event grid reliability is impacted by sympathetic tripping of VERs or other resources, the ISO may initiate a process to extend the low voltage ride-through requirements, and/or initiate a high voltage ride-through requirement prior to NERC action.

3.4 Generator Power Management Requirements

The ISO LGIA currently requires the interconnection customer to comply with all applicable provisions of the ISO Tariff. (LGIA Sec. 3.2) The ISO Tariff, in turn, requires any market participant, including a participating generator, to comply fully and promptly with ISO dispatch instructions or operating orders. (ISO Tariff Sections 4.2.1 and 4.2.2) These requirements exist to ensure the ISO has sufficient control over equipment interconnected to its transmission system to maintain reliability under normal and emergency operating conditions. Innovation in pitch control of wind turbines as well as the advanced power control systems of most OEMs now permits variable generation to, at a minimum, restrict its power output in response to an instruction from the transmission operator and contribute to system reliability when necessary. Nothing in the ISO's proposal regarding power management requires a VER to withhold production capability to be able to *increase* power output in response to a possible instruction from the transmission operator. Nevertheless, the ISO recognizes that actively limiting variable generation output involves the spilling of wind or sun and therefore must be utilized in a very judicious manner consistent with market efficiency and environmental objectives. In order to properly develop appropriate market rules associated with the management of active power, the ISO will engage in a subsequent stakeholder process. Virtually all objections expressed by stakeholders to this component of the initiative were not directed at the capability itself, if not otherwise disruptive to the equipment procurement process, but rather concentrated on the application of the capability and its financial implications. Accordingly, this initiative focuses solely on the basic capability requirements for power management that promote grid reliability and, by doing so, preserves future market design options.

All VER plants, whether synchronous or asynchronous, are required to provide the following power management features:

- Active power management
- Ramp rate limits and control[6]
- Over-frequency response

[6] The discussion in Section 3.4.2 below on ramp rate limits is not intended to apply to solar thermal generators, which it is presumed will reflect ramp rates consistent with the traditional turbine technology adopted for the particular project.

3.4.1 Generation power management

Under Section 4.2 of the ISO Tariff, a Participating Generator, regardless of technology, "shall comply fully and promptly with Dispatch Instructions and operating orders." The only exceptions are if such compliance would impair public health or safety or is "physically impossible." Modern VER plants are physically capable of controlling output as dictated by available wind or insolation and the equipment rating. In fact, the ISO has generally interpreted the physically impossible exception to be restricted to real-time operating circumstances, such as forced outages, start-up times, and, in the case of many renewable resources, lack of fuel, but not predetermined design limitations. Thus, all generating facilities with Participating Generator Agreements are required to operate such that the ISO can control their output under both normal and emergency conditions. (ISO Tariff Secs. 4.6.1.1, 7.1.3, 7.6.1, and 7.7.2.3.) The capability to limit power output from wind generation is already incorporated into operating and market rules in NYISO[7] and AESO[8] among others electric systems.

The need for this capability from a reliability standpoint is straightforward and rests on sound utility practice and commonsense. Situations will occur where the system generally or local transmission facilities in particular, due to contingencies, planned clearances, or unexpected generation output, will be unable to absorb all available generation. Under those circumstances, preserving system security will require the reduction of generation, while necessarily maintaining the operating capability of resources needed for subsequent time periods or other reliability services, i.e., localized voltage support, frequency response, etc.

Based on the foregoing, VER plants must have the ability to limit the active power output in response to a dispatch instruction or operating order. This ability should apply to the VER's full range of potential output (Pmin to Pmax), so that the VER's reduction in output can range from incremental to full curtailment. AESO currently proposes that wind generating facilities must be adjustable from the minimum operating output to the maximum operating output at an average resolution of 1 MW. Reducing the increment of adjustable capacity to its smallest reasonable value allows for greater refinement of the ISO's ability to address the reliability concern and therefore maximizes VER output. The ISO, therefore, believes that adoption of the AESO proposal promotes the objectives of the RPS rules, the economics of VER development, and grid reliability. AESO also requires that the power controls be capable of keeping the 1 minute average MW output of the VER from exceeding the 2% of the VER's specified output directed by AESO, but if a "wind gust" causes the limit to be "instantaneously" exceeded, the VER will remain in compliance if the output does not exceed 5% of the directive. The ISO is not proposing threshold performance requirement for the power controls in terms of its ability to maintain a specified level of output. Rather, the ISO notes that the Tolerance Band for Uninstructed Deviation Penalties, when implemented, is expressed in terms of energy (MWh) for each settlement interval and equals the greater of the absolute value

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[7] *New York Independent System Operator, Inc.*, 127 FERC ¶ 61,130 (2009).

[8] See Section 3.1.5, Market & Operational Framework for Wind Integration in Alberta at http://www.aeso.ca/downloads/MOF_Final__Sept26.pdf.

of: (1) five (5) MW divided by number of settlement intervals per settlement period or (2) three percent (3%) of the relevant Generating Unit's maximum output (PMax), as registered in the Master File, divided by number of settlement Intervals per settlement period. (ISO Tariff, Appendix A.)

The variable generation resource is expected to interface with the ISO in a manner similar to any other generating facility. As such, the VER must be able to receive and respond to Automated Dispatch System (ADS) instructions and any other form of communication authorized by the ISO Tariff. The VER's response time should be capable of conforming to the periods prescribed by the ISO Tariff. In the event that generation management is insufficient, the ISO must have the ability to send instructions to the PTO to disconnect the VER, similar to its authority over any type of generating facility. Also, if a VER is ordered off-line, the plant operator must not reconnect the plant to the grid without prior approval from ISO Operating personnel similar to other generating resources and, as discussed below, may be required to ramp up its output in a controlled manner.

The ISO anticipates using this feature only on an as needed basis to address grid reliability issues or supply surplus situations or based upon stakeholder developed market rules. ISO intends to initiate a stakeholder process to establish rules governing the circumstances and use of this feature prior to beginning to use this feature.

3.4.2 Ramp rate limits and control

VER plants must be able to limit and control their ramp rates, except for downward ramps resulting from the loss of wind or sun to fuel the generating facility. VER plants can have very steep ramp rates as compared to more gradual ramp rates for conventional fuel source resources. Per NERC IVGTF report, some VER generators can change output by +/- 70% in a time frame of two to ten minutes, many times per day.

It is currently envisioned, subject to further stakeholder consideration in a subsequent initiative, that ramp rate limits may be applied when consistent with the generator's economic bidding strategy or for specified operating conditions where accommodating the natural ramp rate of variable energy generators could threaten grid reliability. The ISO does not envision that this functionality will be continuously used and will be activated by an ISO dispatch instruction or operating order. As such, the ISO does not anticipate the need for any special or specific communication procedures or equipment associated with the ramp control features distinct from the general means by which the ISO and generating facilities and their scheduling coordinators interact under existing ISO Tariff authority. The ramp rate limiter will be used only when needed to reliably accommodate the upward and downward ramps for variable energy resources. At the present time, the ISO anticipates limiting ramps when a curtailment instruction is engaged or released. In addition, the ability to limit the rate of power change may be necessary during periods of insufficient aggregate ramping capability on the system, primarily during a significant upward ramp of wind or solar resources.[9]

As noted, Interconnection Customers should design the system such that the ramp rate control feature can be enabled, when needed, in response to an external command from the ISO. The ISO was not intending to specify the rate for up and down ramping at this time, but rather focus on the capability of the equipment to adjust to a range of potential ramp rates. Several stakeholders, including the Large Scale Solar Association, criticized this approach and requested that clearly defined requirements be established. . As a result of stakeholder feedback, AESO has proposed that wind resources have the ability to set their ramp rate between a range of 5% and 20% of rated capacity/minute with a default setting of 10%. Previously, the AESO had a ramp rate limit of 10% of the facility's rated capacity/min. This is an upward ramp rate limit only. A report prepared for ISO New England identified a rate of 5% MW rated capacity/minute as the slowest adopted rate. To provide the clarity requested by stakeholders, the ISO recommends adoption of the AESO approach.

3.4.3 Over frequency response

Frequency response is defined as an automatic and sustained change in the power consumption or output of a device that typically occurs within 30 seconds following a disturbance and is in a direction opposing the change in interconnection frequency. Historically, frequency response has been provided by turbine governor response and frequency responsive load in an Interconnection. As load serving entities mobilize to meet California's RPS objectives of 20% and 33% of energy served from renewable generation, conventional thermal resources that currently provide frequency response will be displaced by wind and solar generators. WECC no longer has a direct governor response "standard." Instead, WECC Minimum Operating Reliability Criteria (MORC) requires governor response from generators, which states that "it is imperative that all entities equitably share the various responsibilities to maintain reliability….To provide an equitable and coordinated system response to load/generation imbalances, governor droop shall be set at 5%." The ISO must meet Applicable Reliability Criteria. Applicable Reliability Criteria includes "[t]he Reliability Standards and *reliability criteria* established by NERC and WECC and Local Reliability Criteria, as amended from time to time… ." (ISO Tariff, Appendix A.)

A conventional synchronous machine typically provides frequency response in the form of inertial response, where some of the kinetic energy stored in the rotating mass is released as electrical energy, and by governor response, where governors act based on

[9] As a general matter, the ISO does not foresee limiting downward ramps that occur because of the absence of fuel for a variable wind or solar generator. The ISO recognizes that absent an event that causes wind speeds to exceed turbine cutout levels, downward wind ramps in the aggregate tend to be over a reasonably substantial period of time. And, while the effect of geographic diversity of solar variability requires additional study, it does appear that spatial dispersion will also mitigate the impact of cloud cover on the aggregate solar portfolio. Moreover, solar downward ramps due to the sun setting are likely to be more severe absent storage, but these types of down ramps are generally predictable. To the extent ramps due to the sunset need to be managed, whether due to reliability needs or generator economic preferences, these events can be addressed through use of the ramp rate control system coupled with dispatch instructions to reduce output prior to sunset. Any implementation of such a scheme must be supported by further analysis of system impacts and costs as well as consideration of appropriate market mechanisms and triggers.

the automatic droop control loop in response to the change in frequency, and open the governor valve to increase the turbine's output. Inertial response is inherent to all synchronous machines. Governor response is via control actions which can be turned to meet performance objectives, and, as has been pointed out by stakeholders, can be disabled, as is the case with some turbine generators designed to operate at full output.

For variable energy generators, the physical equivalent for governor response is provided by control logic, such that the active power output of the generators can be adjusted if the grid frequency deviates from the pre-defined thresholds. The ISO recognizes that the ability of a VER to provide under-frequency response would require spilling wind or sun so that the facility is not maximizing its ability to produce energy. Similar to other types of resources intended to operate at full output, the ISO is not recommending VERs provide under-frequency response.

However, consistent with MORC, the anticipated operation of VERs, and the increase in their percentage of the overall generation portfolio, the ISO will require over frequency response all variable energy generators. Variable generation resources must have an over frequency control system that continuously monitors the frequency of the transmission system and automatically reduces the real power output of the generator in the event of over frequency. An intentional dead band of up to 0.036 Hz can be designed for the over frequency control system. The ISO believes that if variable energy generators provide over frequency response, then the risk of their receiving a disconnect order from the ISO in over frequency situations would be reduced. The over frequency response design requires a droop setting of 5%, which means that a generator will change its output 100% for a 5% change in system frequency.

3.4.4 Exemptions and transition period

As stated above, the ISO does not intend to activate the generation management capabilities until after the conclusion of subsequent stakeholder initiatives to review and potentially revise market rules and operational protocols designed to increase VER participation in ISO markets increase and to generally improve the efficacy of the ancillary services market to manage VER variability and uncertainty. These initiatives are scheduled to commence in Q2 or Q3 of 2010. If it is assumed that the capabilities should be available coincident with the implementation of the previously-described initiatives, the ISO recommends establishing a compliance date of January 1, 2012 or the VERs commercial online date, whichever is later, for the generation management requirements. However, VERs with a signed LGIA, LGIA filed with the Commission in unexecuted form, or tendered for negotiation prior to the date this policy is approved by the ISO Board of Governors will be exempt from the requirements, but may voluntarily elect to install such capability based on the subsequently developed market rules and operational protocols.

The exemption and transition recommendations rest on the understanding that such capability is currently available from multiple OEMs for both wind and solar photovoltaic technologies. Given the commercial availability, coupled with the ISO's understanding that equipment procurement generally succeeds LGIA execution, the ISO believes the scope of exemptions will not impact development timing. However, to the extent a non-exempt facility can demonstrate a binding commitment to purchase non-compliant equipment as of the exemption cut-off date, the ISO will consider the specific capability of the resource's equipment to develop requirements for the individual project that are consistent that capability. Such projects will be subject to submission of a non-conforming LGIA. As noted, the ISO anticipates that the universe of potential projects in this category will be small to non-existent based on the sequencing of development events and the relatively short lead time for delivery of control equipment.

3.5 Interconnection Application Data Recommendation

The ISO recommends Interconnection Customers provide the ISO with WECC approved standard study models (standard models) for their projects, rather than user-defined models, to the extent standard models are available. If standard models for certain generator technologies are not yet available, then the Interconnection Customers can supply user-written or equivalent models. However, once standard models become available, the Interconnection Customers should begin providing standard models. This not only helps in expediting the study process but ensures better consistency and higher confidence in accuracy of study results.

3.6 PSS Requirement

Article 5.4 of ISO LGIA requires PSS for all generators except Induction type wind plants. This Article will be modified such that the PSS requirement exception extends to all asynchronous generators, including Induction type wind plants and asynchronous solar plants.

4. Future Analysis

Several other topics need to be closely reviewed for reliable renewable integration. The ISO is not adding any Interconnection Requirements on these topics for this phase of the initiative, but the ISO will be reviewing any adverse reliability impacts in future phases of this initiative to determine if any new Interconnection requirements need to be developed:

4.1 Inertial response

Large interconnected systems generally have large aggregate inertia, which helps in automatic arresting of frequency decay following the loss of generation resources. The lower the system inertia, the faster the frequency will change and the larger the frequency deviation will be if a variation in load or generation occurs. As the share of variable energy generators increases in the system, the effective inertia of the system is expected to decrease considering the existing technologies. Conventional synchronous generators inherently add inertia to the system, but it is not typically the case with many renewable technology generators. The ISO may need to undertake an analysis of the impact of reduction in system inertia due to large scale variable energy generation displacing conventional synchronous machines. Pending the outcome of this analysis, there may be a need to develop new system operating limits, so that the MW amount of non inertia-responsive generation can be reduced to maintain reliability for certain operating conditions. Controls providing inertial response for some types of VERs and energy storage technologies may provide a substitute for the automatic injection of energy provide today by system inertia. The ISO will consider the capability of these technologies as potential mitigation for these operating limits.

4.2 AGC participation

The ISO will analyze if there a need to mandate any new generation, including variable energy generation, to participate in Automatic Generation Control (AGC). It should be noted that ISO's asymmetric regulation market offers variable generators the opportunity to participate in that market for regulation down without continuously spilling wind or sun in order to maintain a regulation up range.

4.3 Under frequency response

The ISO may need to analyze if there is a need to mandate variable energy generation to provide under frequency response. If so, CAISO will require and utilize this feature in a very judicious manner consistent with market efficiency and environmental objectives. In the event market rules associated with the use of active power are necessary, the ISO will engage in a subsequent stakeholder process.

4.4 Impact of the reduction in fault current levels

The inherent characteristics of practical asynchronous generators result in reduced short-circuit current contribution. A key disadvantage of this is that short circuit faults may not clear, because standard protective relaying relies on the presence of significant fault current from at least one of the terminals of a transmission line or transformer. Significantly reduced fault current may result in time delayed clearing of system faults, and in the worst case, the relaying may fail to detect or clear the fault. The ISO intends to confer with the PTOs to examine the impact of reduced available fault current.

4.5 Power quality issues

Power Quality refers to maintaining a pure sinusoidal output of voltage and current, and that frequencies other than the fundamental 60 Hz are not present. Further, there should be no noticeable flicker in system voltage associated with routine switching for lines, capacitors, etc. ISO intends to engage with Power Quality Standards agencies (IEEE, ANSI) to analyze the impact of any additional Power Quality issues that may be caused by inverter-based variable energy generation.

4.6 Minimum dynamic voltage support needs

As VERs deploy on large scale and displace some existing synchronous generation capacity, the need for dynamic voltage support for the grid will increase. The ISO may need to undertake a study to establish a minimum amount of dynamic voltage support requirements for new generation projects.

4.7 Impact of VERs on distribution system

If variable energy generators are developed on large scale at the Distribution system level, then any adverse impact of this penetration on the Transmission system will need to be analyzed. The interconnection requirements for new generators connecting to the Distribution system are different and in some cases in conflict with interconnection requirements for the Transmission system. One such conflict exists between IEEE 1547 & UL 1741 standards that require inverter-based generation to trip offline for faults near a generator due to low voltages at the inverter terminals. If a significant amount of generation on the Distribution system starts tripping for faults, this will pose an added burden on the Transmission system. NERC IVGTF Taskforce for Task 1.7 is working on addressing this issue. The ISO will stay engaged in this NERC activity and may undertake additional tasks to analyze the impact of this issue.

4.8 Non fundamental frequency interactions

VER technologies that rely on power inverters have high frequency bandwidth controls. These controls have the potential to interact with other power electronic based equipments (e.g. HVDC transmission), synchronous turbine-generators and series capacitors. ISO intends to monitor industry developments on this issue.

5. Next Steps

The ISO requests that stakeholders provide written feedback to the ISO on this draft Final Straw Proposal. Written comments should be submitted to the ISO no later than April 30, 2010 to irrp@caiso.com.