Interconnection Standards Review Initiative

Draft Straw Proposal

March 25, 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 standards, 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 standards for new large generating facilities, i.e., those facilities that area equal to or greater than 20 MW. The scope and summary of the ISO's proposal is set forth in the next section below. Although prompted by the need to clarify the expected contribution of variable generation to system reliability as they become a significant portion of California's generation portfolio, the ISO seeks to adopt uniform standards, whenever possible, that apply to all generation technologies. Nevertheless, 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 standards not only within the ISO, but regionally and nationally. As such, the ISO would prefer to defer to ongoing efforts at NERC and WECC to also redefine interconnection requirements. The ISO intends to coordinate with NERC and WECC processes and, more important, seeks to explore means to ensure the convergence of any standards developed through this initiative and those ultimately approved by those entities.

However, the ISO believes this initiative must proceed in parallel with NERC and WECC efforts and conclude expeditiously. The ISO has over 21,000 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. This means sufficient renewable capacity capable of satisfying

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[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.

California's ambitious 33% maximum extent possible while respecting commercial realities.

The ISO intends to work with the stakeholders to finalize any refinements to the interconnection standards by the end of April 2010, seek Board of Governors approval in May 2010, and file any necessary changes to the LGIA with FERC 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 15, 2010	Publish Revised Final Straw Proposal
April 21, 2010	Stakeholder Conference Call and Comments
May 17, 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

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 standards surrounding active power control. 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. This must be emphasized – 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 active power control 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 will be 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. However, foregoing a discussion of the capability requirements pending the outcome of new market rules will not eliminate potential uncertainty, but can unacceptably jeopardize future grid reliability, lead to blunt or suboptimal 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. Some recommendations in this proposal apply to all types of generation facilities, whereas other recommendations apply only to Variable Energy Resource (VER) plants that use inverters or other types of asynchronous generators.

B. The new interconnection standards proposed in this document will become applicable after FERC approves the ISO's filed LGIA with changes associated with these requirements.

C. The recommendations are not intended to be applied retroactively to any interconnection project with an executed LGIA prior to their adoption by FERC. Moreover, the ISO intends to explore the equity of exempting certain interconnection projects on the basis of other commercial circumstances, including, but not limited to, the prior procurement of equipment or the execution of a power purchase agreement that does not permit recovery of incremental costs resulting from compliance with the revised standards. The proposed exemptions are discussed separately for each requirement.

D. Recommendations regarding market policies and procedures are beyond the scope of this initiative.

E. The ISO notes that the requirements specified herein may be subject to change in the event that NERC or WECC adopt requirements covering the same subject matter and the ISO and/or generation facility is required to comply with such NERC or WECC standards. Accordingly, the ISO will attempt to make the requirements as consistent with standards pending before NERC or WECC as possible and will adopt the NERC or WECC standards when they are finalized.

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 to be 0.9 lag/0.95 lead, measured at Generator terminals. • Appendix H of LGIA establishes power factor requirement for Wind generators to be 0.95 lag/0.95 lead, measured at POI.	• Recommend that power factor requirement for all generators, except asynchronous VERs is 0.9 lag/0.95 lead, measured at Generator terminals. Add some clarification about interpretation of 0.9 lag/0.95 lead requirement. • Recommend that power factor requirements for asynchronous VERs (such as

Requirement	What is in place today?	What is the proposal?
	• Appendix H of LGIA provides that the system impact study (SIS) must justify the need for power factor requirements. • There is a discrepancy between ISO tariff & LGIA about the point where power factor requirements should be measured.	asynchronous wind generators, solar PV) is 0.95 lag/lead, measured at POI. • Establishes a default power factor requirement for all resources. • Eliminates inconsistency by bringing the tariff & LGIA requirements in line, as per the recommendation in 1e), 1f), 1g) above.
2) Voltage Regulation Requirements	• Article 9.6.2 of LGIA establishes the requirement for an Interconnection Customer ("all" generators) to maintain Voltage Schedules.	• Adds further details on implementing voltage regulation mechanisms. This requirement applies to "all" generators.
3) Voltage & Frequency ride-through requirements	• Currently the only voltage ride through requirement in 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 in WECC Off-Nominal Frequency plan.	• Recommend NERC PRC-024-1 standard requirements for Low & High Voltage ride for all generators. • Recommend that all new generators, including all VER plants must comply with the existing WECC requirement.
4) Generator Power Management Requirements	• Active Power Management - Currently 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 & Control – Currently there is no reference to the need for ramp rate limit/control in ISO tariff. Conventional fuel source machines typically have "gradual" ramp rates, whereas	• All VERs must install control systems that provide for active power management, including the capability to limit ramp rates and respond to over-frequency conditions.

Requirement	What is in place today?	What is the proposal?
	VER plants could have very "steep" ramp rates, which could cause reliability issues in accommodating ramps. • Over-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 VER plants to provide any frequency response.	
5) Interconnection Application Data	• No requirement for submitting standard study models for LGIP studies.	• Require use of standard study models, if available.
6) PSS Requirement	• Article 5.4 of ISO LGIA requires PSS 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 Requirements

3.1.1 Power Factor Requirement for asynchronous VER plants

ISO proposes that asynchronous VER plants should be capable of providing reactive power output within 0.95 lag to 0.95 lead as measured at the Point of Interconnection (POI), to maintain specified voltage schedule. All VER plants should be designed such that the reactive power range corresponding to 0.95 lag and 0.95 lead at **rated power output** shall be available at all active power production levels above the minimum operating active power level (Pmin) for the plant. The power factor range standard can be met by using, for example, power electronics designed to supply this level of reactive capability (taking into account any limitations due to voltage level, real power output, etc.) or fixed and switched capacitors, or a combination of the two, if agreed to by the Participating TO and CAISO. The reactive power output may need to be continuously variable, in order for the plant to regulate voltage.

The 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. 661a. However, the ISO proposes the following key items related to this recommendation:

(a) Wind power factor requirements (0.95 lag to 0.95 lead) should apply to all asynchronous VER plants, with the interpretation of this requirement as per the description above.
(b) The requirement should apply without having to demonstrate the need for this requirement through specific Interconnection Studies. (*This reflects a change from the current FERC Order No. 661a standard, which puts the onus on the transmission operator to demonstrate the need for reactive power.*)

The ISO believes that extending the existing Order No. 661a standard beyond wind facilities to solar photovoltaic generators is appropriate given the similarity in power converter systems used by both technologies as well as the fact that both types of facilities consist of multiple generating units. As with conventional synchronous generators, this requirement does not require that equipments within the plant, including generators, be required to violate ratings to meet the power factor requirements. Given the existing wind standard, the ISO understands that power converter system equipment capable of meeting this standard is commercially available from multiple suppliers and can be used or readily converted for use by solar photovoltaic generators. This conforms to the fact that interconnection customers with wind and solar photovoltaic facilities that have entered into LGIAs with the ISO that meet or exceed this standard based on existing power factor requirements. Accordingly, the ISO does not propose an exemption or transition for this standard, but will consider means for those asynchronous generators that have entered into an LGIA in conformance with the current ISO LGIA power factor standard can voluntarily comply with the updated standard.

3.1.2 Power Factor Requirements for all generating plants (except asynchronous VERs)

The power factor requirements for all generators (except asynchronous VERs) is recommended to be the same as currently defined in Article 9.6.1 of the LGIA. Additional interpretation about this requirement, however is proposed to be added to this Article, as described below.

All generating plants (except asynchronous VER plants) connecting to the ISO Controlled Grid should be capable of providing reactive power output within 0.90 lag to 0.95 lead as measured at the Generator Terminals, to maintain specified voltage schedule. All plants should be designed such that the reactive power range corresponding to 0.90 lag and 0.95 lead at **rated power output** shall be available at all active power production levels above the minimum (Pmin) operating active power level for the plant.

Also, the language in Article 9.6.1 of LGIA is proposed to be revised so that Appendix H applies to all asynchronous VER plants, and the pertinent language of Appendix H would be revised as per the recommendations in 1.1 above. In addition to proposed changes to LGIA Article 9.6.1, changes will be made to “Section 8.2.3.3. Voltage Support” of ISO tariff to be consistent with the above recommendations.

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 VER plants. In order to reliably operate the transmission system within acceptable voltage range at the POI and to be compliant with NERC & WECC standards, it is required that all new generators connecting to ISO Controlled Grid adhere to these requirements. The requirements below outline some specifics related to designing the Voltage Regulation mechanism:

3.2.1 Install Automatic Voltage Regulation mechanism 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 generating facility's reactive power output should be under the control of Automatic Voltage Regulation system.

3.2.3 Co-ordinate with the Participating Transmission Owners (PTO) and the ISO for voltage schedule requirements at the POI. Also, in case there are multiple projects requesting interconnection at the same POI, co-ordination is needed between interconnection customers and the PTO so that the voltage control logic to maintain POI voltage within acceptable levels can be designed.

Each generation facility should design their systems so they can operate in voltage control mode or power factor control mode. Based on the voltage schedule or power factor set point supplied to the facility, the generation facility should be able to perform a closed loop control to produce / absorb VARs in such a fashion as to meet the desired voltage / power factor setting at the POI. The desired default mode of operation for generators is voltage control mode and not power factor control mode.

3.3 Ride-through Capability Requirements

In order to maintain reliability of the grid, it is critical that all new Large Generating Facilities (conventional & VER plants) be designed with fault ride-through capability. The ride-through capabilities required are (a) high and low voltage ride-through and (b) high and low frequency ride-through. The reliability need for ride-through standards, current or proposed standards, and the recommendation for all plants is discussed in the section below.

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. This high voltage condition near generating plants may be magnified due to the high level of shunt capacitors that are installed within the generating plant for power factor correction or voltage control.

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 are utilizing 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 soon after the transient voltage and/or frequency condition is observed. Also, once the generation plant is tripped off-line, it is required to stay off-line for five minutes after the fault. This presents a fundamental conflict. 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 is connected. When the load and generation are precisely balanced, the frequency will 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 from 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

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[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

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, a few voltage ride-through standards exist. FERC Order No. 661a describes the LVRT standard for wind generators. The requirements for this standard are in Appendix H of the ISO LGIA. LVRT standards for all generators are also in place in Germany (per German MV Grid Code), Canada and several other countries. Within United States, a regional VRT standard is under development - NERC PRC-024-1 standard. The details of this standard development activity are outlined below.

NERC-PRC-024-1 standard “Generator Performance During Frequency and Voltage Excursions” 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 the NERC PRC-024-1 standard 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 WECC Reliability Council have been participating in development of NERC Standard 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 VRT criteria. NERC has incorporated most of WECC’s work in developing WECC VRT criteria has been rolled over into NERC’s PRC-024-1 standard development.

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

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 frequency ride through requirements are listed in Table 1 of "Reference D: WECC ONF, Apr. 1, 2005" within this document. The ISO recommends new projects to be designed to be compliant with meeting WECC ONF Plan requirements, rather than requirements in NERC PRC-024-1. ISO's discussion with NERC PRC-024-1 standard development team members revealed that WECC is aware of this potential conflict, and intends to seek a regional variance from NERC PRC-024-1 standard for frequency ride through requirements. Table 2 below lists under/over frequency limits and WECC minimum times as per the WECC ONF Plan.

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:

ISO recommends designing all new generation facilities so that they can comply with the substantive voltage ride through criteria as specified in draft 2 of NERC Standard PRC-024-1. The ISO is unwilling to abstain from establishing a standard at this time in favor of an unconditional deference to the NERC process. The ISO believes it cannot assume the risk of an uncertain process and, more importantly, one whose timing and potential applicability, i.e., retroactivity and facility size, may be inconsistent with ISO reliability needs. For example, if the NERC standard is not approved until 2011 and applies only prospectively, a substantial amount of MW may interconnect to the ISO grid without any requirement to comply with essential ride-through capability. Moreover, the NERC standard, as currently drafted, would exclude a significant subset of Large Generating Facilities, i.e., multiple generating units less than 75 MVA.

The ISO acknowledges, however, that some lag will occur between the adoption of the standard and the availability from OEMs of inverters capable of meeting the standard. The ISO considers Order No. 661a a model for addressing the transition. In that order, FERC agreed to a transition period for wind facilities that had executed LGIAs or that had power purchase agreements in place that were set to deliver prior to a certain date. Similarly, a transition period should be allowed here for those facilities with LGIAs, including conventional generators, or those with commercial online dates that come before the transition period expiration. Further, the transition period should be designed to accommodate the fact that certain projects may be procuring equipment prior to the commercial availability of the ride-through capability.

3.3.4.2 Frequency Ride-through capability:

ISO recommends designing the new generation facilities so these can comply with the off-nominal frequency requirements as per WECC ONF plan. 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 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 VER plants need to comply with this requirement. ISO's understanding is that most VER plants are currently not designed as per WECC frequency ride-through requirements.

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 dispatching instruction 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 many OEMs now permits variable generation to control power output and contribute to system reliability when necessary. The ISO recognizes, however, that actively controlling 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. This initiative is limited to providing basic capability requirements for power management that promote grid reliability and do not foreclose future market design options.

Therefore, all VER plants, whether synchronous or asynchronous, are required to provide the following power management features:
(3.4.1) Active power management, (3.4.2) Ramp rate limits & control and (3.4.3) Over-frequency response.

3.4.1 Active 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 their 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.)

Based on the foregoing, VER plants must have the ability to control the active power in response to a dispatch instruction or operating order similar to conventional generators. This ability should apply to the VER plants' full range of potential output. The variable generation resource also should be able to receive Automated Dispatch System (ADS) instructions from the ISO Control Center and adjust the active power output of the plant to address any grid reliability concerns. In the event that active power control is not sufficient, the ISO must have the ability to send instructions to remotely trip the plant off-line. Also, if a VER plant is ordered off-line, the plant operator should not connect the plant back to the grid without prior approval from ISO Operating personnel.

The ISO anticipates using this feature only on an as needed basis to address any 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. 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 phase of this initiative, that ramp- rate limits will be imposed 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. It will be used only when needed to reliably accommodate the upward and downward ramps for variable energy resources. Interconnection Customer should design the system such that the Ramp Rate control feature can be enabled, when needed, either by the plant operator or in response to an external command from the ISO. This ability to enable or disable ramp rate limits is valuable to the grid. 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.[6]

The ISO is not requiring any set limits for ramp up and down at this time. Alberta ISO has adopted a 10% MW rated capacity/minute upward ramp rate limit. A report prepared for ISO New England identified a rate of 5% MW rated capacity/minute as the slowest such adopted rate. If during the stakeholder process, it is determined that specification of a ramp rate is necessary to define the equipment specifications or guide the OEM development process, then the ISO will solicit feedback on the appropriate ramp rate.

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

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[6] 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 wind speed in excess of turbine cutout levels, downward wind ramps in the aggregate tend to be over a reasonably substantial period of time. Solar downward ramps due to the sun setting are likely to be more severe absent storage. But these types of solar down ramps can be addressed through active power control limits coupled with dispatch instructions to curtail 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.

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.

A conventional synchronous machine typically provides frequency response in form of inertial response, where some of the kinetic energy stored in the rotating mass is released as electrical energy and governor response, where governors act based on the automatic droop control loop for 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 also can be disabled, as is the case with some turbine generators. 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. WECC Minimum Operating Reliability Criteria (MORC) requires governor response from generators within WECC. Per WECC MORC, "[I]t 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%."

Over frequency governor response is required from all variable energy generators, just like it is from conventional fuel source 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 requirements area droop setting of 5%, which means that a generator will change its output 100% for a 5% change in system frequency.

3.5 Interconnection Application Data Recommendation

The ISO recommends Interconnection Customers to 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 is provided 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. While 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 from these topics 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 will analyze 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 VER plants and energy storage technologies may provide a substitute for the automatic injection of energy provide today by system inertia. ISO’s analysis 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 will analyze if there 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 order to properly develop appropriate market rules associated with the use of active power, 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 will work 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 will be engaging 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 variable energy generation continues to be developed on large scale and this displaces some existing synchronous generation capacity, the need for dynamic voltage support for the grid would increase. ISO will undertake a study to establish minimum amount of dynamic voltage support requirements for new generation projects.

4.7 Impact of Variable Energy Generation Development 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 generator station that can cause low voltages at the inverter terminals. If 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. ISO will stay engaged in this NERC activity and may undertake any additional tasks required 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 will stay engaged in industry developments on this issue.

5. Next Steps

The ISO requests that stakeholders provide written feedback to the ISO on this Straw Proposal. Written comments should be submitted to the ISO no later than April 8, 2010 to irrp@caiso.com. Comments received by the ISO will be posted to the ISO webpage and considered as the interconnection standards are reformed.