PERFORMANCE REQUIREMENTS FOR TRANSMISSION-CONNECTED NON-SYNCHRONOUS RESOURCES

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1. SCOPE

The technical requirements in this Requirements Document shall apply to all energy producing and energy storage resources that are to be directly interconnected with the LIPA transmission system and use means of conversion of mechanical or electrical power to alternating current or voltage at the system nominal frequency (60 Hz) by other than synchronous generators. The transmission system is defined as the portion of the LIPA system having a nominal voltage of 23 kV or greater.

This Requirements Document is not applicable to transmission-connected resources using synchronous generators nor is it applicable to resources connected to the LIPA distribution systems.

2. DEFINITIONS

Dynamic reactive power: *Dynamic reactive power* capability shall be defined as the ability to inject or absorb reactive power over the required range with continuous variability, time response as defined in this Requirements Document, and with indefinite repeatability of cycling.

Frequency deadband: The range of fundamental power system frequencies around the nominal frequency value of 60.000 Hz for which there is no response in active power control commands.

Frequency disturbance: Event in which the fundamental power frequency exceeds the defined *frequency deadband.*

Nominal short-circuit capacity: For the purposes of this Requirements Document, *nominal short-circuit capacity* is defined as the short-circuit capacity at the Resource Point of Interconnection with no transmission line or other transmission equipment outage contingencies and with all generation interconnected with the LIPA system disconnected.

Nominal short-circuit ratio**:** The ratio of the Resource's *nominal short-circuit capacity* at the Point of Interconnection with the LIPA system, in MVA, divided by the aggregate MVA rating of all inverter-based units within the Resource facility, inclusive of inverter-based equipment intended only for reactive power support (e.g., STATCOMs).

Remain on line**:** Performance in which the Resource does not trip (open mechanical breakers) and does not cease injection of current for voltages except where voltage magnitude is less than a defined undervoltage threshold, or greater than a defined overvoltage threshold, and momentary cessation is permitted provided current injection is resumed according to defined criteria.

RMS magnitude: Root-mean-square magnitude of the quantity measured over a single fundamental-frequency period.

Transmission event: A disturbance of the transmission inclusive of single- and multi-phase faults, line switching, cable switching, transformer energization, generator tripping, etc. The event is inclusive of all transmission system dynamic response to the initiating events. Successful and unsuccessful line reclosing with less than 30 seconds delay shall be considered as a single event. Reclosing with greater than or equal to a 30 second delay shall constitute an independent event.

Voltage disturbance: Event in which the phase-to-ground or phase-to-phase voltage at the Point of Interconnection exceeds +/- 10% of nominal voltage or the voltage phase angle suddenly changes or "jumps."

3. REACTIVE POWER CAPABILITY AND CONTROL

3.1 Reactive Power Capability in Continuous Operation

The following requirements apply when voltage at the Point of Interconnection (POI) with the LIPA system is greater than or equal to 0.90 per unit (p.u.), and less than or equal to 1.10 p.u. of the nominal LIPA system voltage[1].

a) The Resource shall have the capability of delivering reactive power to the LIPA transmission system (lagging, or over-excited operation) at the POI that is at least 33% of the Resource's rated active power capacity, when the voltage at the POI is at the nominal magnitude, at all levels of active power output or input in excess of 20% of the Resource's rated active power capacity.

b) The Resource shall have the capability to absorb reactive power from the LIPA transmission system (leading, or under-excited operation) at the POI that is at least 33% of the Resource's rated active power capacity, when the voltage at the POI is at the nominal magnitude, at all levels of active power output or input in excess of 20% of the Resource's rated active power capacity.

c) At non-zero active power output or input levels less than or equal to 20% of the Resource's rated active power capacity, the Resource shall be capable of reactive power in proportion to active power that is equivalent to a net power factor at the POI

[1] Voltage greater than 1.05 p.u. and less than 1.10 p.u. is outside of the normal operating range for interconnections at 69 kV (nominal) and above, but the Resource shall provide the reactive power capability defined in this clause for as long as the Resource is required to remain in operation. High-voltage ride-through requirements are specified in Clause 4.1.

between 0.518 leading to 0.518 lagging. Reactive power requirements at nominal voltage are graphically illustrated in Figure 3-1.

d) Reactive power capability requirements, as a percentage of the reactive power capability requirements at nominal voltage, are specified in Figure 3-2 for off-nominal voltages within the normal operating voltage range.

e) The Resource shall provide reactive power, as specified in Sub-Clause 3.1 (a through d) as *dynamic reactive power* over the range of active power export (and import, in the case of energy storage) without the requirement to mechanically switch any reactive compensation device or change any transformer tap.

   If a Project's rate of change in active power flow under normal operating conditions (e.g., variations of wind speed or solar irradiance, or response to dispatch) is less than 0.5 per-unit of rated active power capacity per minute, the following exceptions to this requirement apply:

   1) Mechanically-switched shunt capacitors or reactors may be used to contribute to the reactive power requirements up to an amount equal to the net reactive power losses or gains of the Resource's balance of plant. Switching of these capacitors or reactors may be performed to accommodate changes in the Resource's active power, but not to accommodate changes in the POI voltage. Limitations such as capacitor discharge time or switchgear cycling limits shall not constrain the Resource from providing the required reactive capability during active power variations.

   2) Change of on-load transformer taps may be used to maintain adequate voltages within the Resource only to accommodate changes in active power. For a fixed active power, the Resource shall be able to provide the full range of required reactive power, over the full range of POI voltage, as defined by Figures 3-1 and 3-2, without change of transformer taps.

f) Active power delivery by the Resource shall not be limited or constrained by the delivery or absorption of reactive power as specified in 3.1(a through d) when voltage at the POI is within the range of 0.90 to 1.10 per-unit of the nominal voltage. This requirement is not applicable to energy storage in the charging mode.

g) When the Resource is not exporting active power to, or importing active power (in excess of auxiliary load requirements) from, the LIPA system, the reactive power flow across the POI, leading or lagging, shall not exceed the lesser of 2% of the *nominal short-circuit capacity* (MVA) of the LIPA system at the POI or 20 MVAR. This requirement shall apply, non-exclusively, to start-up and shutdown sequences (but does not apply to energization inrush transients) and periods of resource nonavailability during which the Resource remains connected to the LIPA transmission system.

h) For the purposes of defining reactive power capability in normal operation, as specified in this sub-clause, the applicable voltage magnitude shall be the positive-sequence fundamental-frequency component of voltage at the point of resource facility interconnection with the LIPA transmission system.

Figure 3-1 Required reactive capability, at nominal voltage, as function of Resource power output or input.

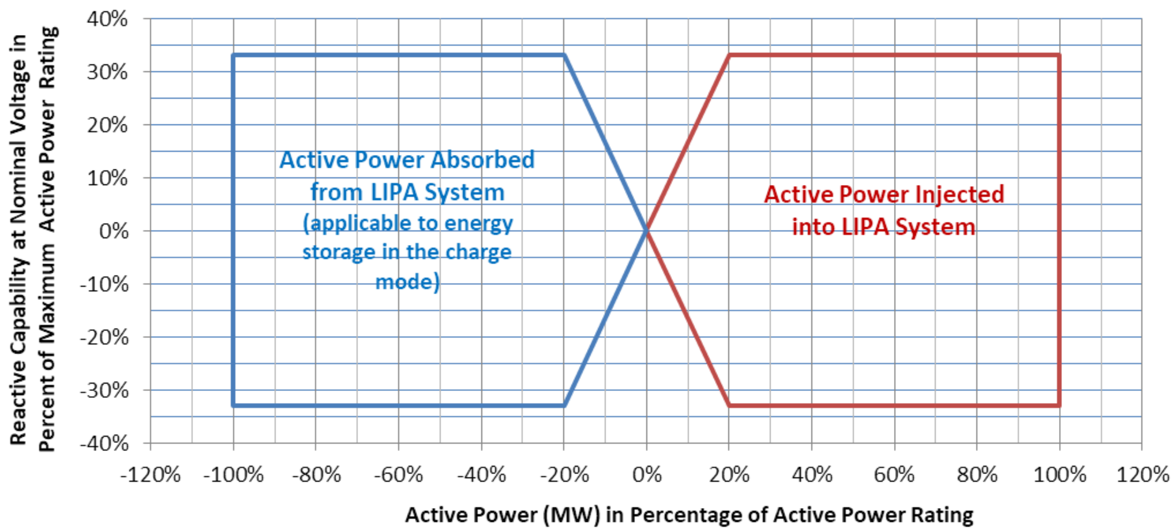
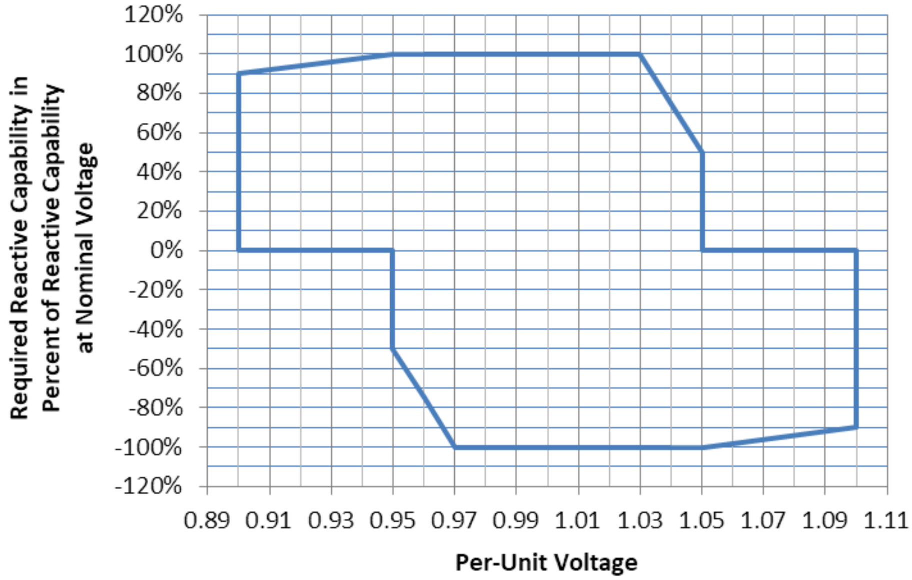


Figure 3-2 Required reactive capability as function of POI bus voltage. Positive percentage indicates overexcited (lagging) reactive power, negative percentage indicates under-excited (leading) reactive power.



3.2 Reactive Power Control Capability

When the voltage at the POI is between 0.90 p.u. and 1.10 p.u. of the nominal voltage, the Resource shall have the control capability to regulate its reactive power in any of the following modes: constant reactive power, constant power factor, bus voltage regulation with droop. These control modes shall achieve specified performance at the POI, regardless of whether the Resource is composed of a single generation or energy storage unit, or a multiplicity of individual units.

3.2.1 Constant Reactive Power Mode

a) In the constant reactive power mode, the net reactive power at the POI shall be automatically maintained at a specified value or setpoint. The minimum range of adjustability for this setpoint shall at least cover the full range of required reactive power capability as specified in Sub-Clause 3.1 of this Requirements Document.

b) The steady-state reactive power flow into or out of the LIPA system at the POI shall be maintained at the more constraining of the reactive power regulation setpoint and the reactive power capability of the Resource, as specified in Sub-Clause 3.1 of this Requirements Document, within tolerances of +/- 2% of the Resource's active power rating.

c) Transient changes of voltage, for which the initial and final phase voltage magnitudes are within the voltage range of 0.90 p.u. to 1.10 p.u. of nominal, and any changes of the Resource's active power generation, shall not cause the net reactive power at the POI to vary outside of the specified steady-state reactive power tolerances for a duration in excess of 5.0 seconds.

3.2.2 Constant Power Factor Mode

a) In the constant power factor mode, the net reactive power at the POI shall be automatically varied in proportion to the active power output, such that a constant power factor is maintained at a specified setpoint. The minimum range of adjustability for this setpoint shall be from 0.95 leading to 0.95 lagging.

b) The steady-state reactive power flow into or out of the LIPA system at the POI shall be maintained at the more constraining of the constant power factor setpoint and the reactive power capability of the Resource as specified in Sub-Clause 3.1 of this Requirements Document, within tolerances of +/- 2% of the Resource's active power rating.

c) Transient changes of voltage, for which the initial and final phase voltage magnitudes are within the range of 0.90 p.u. to 1.10 p.u. of nominal), and any changes of the Resource's active power export or import, shall not cause the net power factor to deviate from the specified steady-state tolerances for a duration in excess of 10.0 seconds.

3.2.3 Voltage Regulation Mode (with Droop)

a) In the voltage regulation mode, the reactive power of the Resource shall be automatically varied to regulate the POI positive sequence voltage magnitude to a specified setpoint, offset by a droop function.

b) The minimum range of adjustability for the voltage regulation setpoint shall be from 0.95 to 1.05 p.u. of the nominal voltage.

c) The voltage regulation setpoint shall be offset by a droop function that is in proportion to the reactive power output of the Resource.

d) The minimum range of adjustability for the droop function shall be from 0.0 to 0.30 p.u. voltage setpoint offset per per-unit reactive power output. The per-unit base for the reactive power output is the rated apparent power (MVA) capacity of the Resource.

e) The Resource shall not be required to provide reactive power greater than as specified in Sub-Clause 3.1 of this Statement in order to regulate voltage. Controls shall be designed to avoid "wind-up" of integral functions when the reactive power output is limited by capacity constraints.

f) The voltage regulation function shall maintain the steady-state POI positive-sequence voltage magnitude to within ±0.005 p.u. of the specified voltage regulation setpoint, as adjusted by the droop function, to the extent that this voltage regulation performance can be achieved within the reactive capability limits of the Resource.

g) The voltage-regulation function shall have a closed-loop response time not greater than 10.0 seconds with *nominal short-circuit capacity*. Response time is defined as the time from when a step stimulus is initiated (e.g., switching of an external reactive device such as to cause a step change in the voltage) until the Resource reactive power output has reached 90% of its final value. Faster response may be desirable, if achievable with the stability margins defined in 3.2.3(h), (i), and (j).

h) For a step change in the LIPA system (e.g., switching of a capacitor bank) and with the LIPA system at the *nominal short-circuit capacity*, the resulting Resource reactive power response shall not overshoot the final value by more than 10% of the change in steady-state reactive power.

i) For a step change in the LIPA system (e.g., switching of a capacitor bank) and with the LIPA system at the weakest single-contingency (N-1) short-circuit strength, the resulting Resource reactive power response shall not overshoot the final value by more than 20% of the change in steady-state reactive power.

j) The voltage regulation control shall remain stable for any LIPA system short-circuit capacity at the POI greater than the short-circuit capacity provided by the most severe N-1-1 contingency.

3.2.4 Dispatch of Reactive Power and Voltage Control Setpoints and Parameters

a) The selection of the reactive control mode and setpoints shall be at the sole discretion of PSEG-LI System Operations.

b) Changes in control mode and setpoints may be changed at any time. The Resource Owner shall be responsible for implementing any ordered changes immediately. In all cases, these changes shall be initiated within ten (10) minutes of issuance of the order by PSEG-LI System Operations.

c) Changes in the reactive power setpoint of the constant reactive power control mode shall be implemented as a gradual change at a rate between ± 0.1 p.u. and ±1.0 p.u. of the Resource's active power rating per minute.

d) Changes in the voltage setpoint of the voltage regulation mode shall be implemented as a gradual change at a rate between ± 0.01 p.u. and ±0.1 p.u. of the nominal voltage per minute.

3.3 Reactive Power Capability During Voltage Disturbances

This sub-clause specifies the physical reactive power capability of the Resource when the POI voltage is less than 0.90 p.u. or greater than 1.10 p.u. of the nominal voltage. Deployment and control of this reactive power is specified in Clause 4 of this Requirements Document.

a) The Resource shall have the capability to deliver reactive power to the LIPA transmission system (lagging, or overexcited operation) at the POI that is at least 33% of the Resource's rated active power at nominal voltage when the positive-sequence voltage at the POI is less than 0.90 p.u., and greater than 0.5 p.u., of the nominal voltage.

b) Injection of reactive current at POI voltage less than or equal to 0.5 p.u. of the nominal voltage is not required.

c) Active current injection may be curtailed to meet the reactive current injection requirements during undervoltage conditions that are specified in this sub-clause.

d) The Resource shall have the capability to absorb reactive power from the LIPA transmission system (leading, or under-excited operation) at the POI that is at least 33% of the Resource's rated active power at nominal voltage, when the positive-sequence voltage at the POI is greater than 1.10 p.u. and less than 1.2 p.u. of nominal voltage.

e) The minimum required durations of reactive power injection or absorption when voltages are outside the 0.90 – 1.10 p.u. range shall be defined by the voltage ride-through requirements specified in Clause 4.

4. VOLTAGE AND FREQUENCY DISTURBANCE PERFORMANCE

In order to minimize power resource deficiencies in the LIPA system as a result of system voltage and *frequency disturbances* that may affect multiple power generation resource facilities simultaneously, ride-through performance requirements are set forth in this clause.

4.1 Voltage Disturbance Ride Through

a) The Resource shall *remain on line* for the *voltage disturbance* caused by any single or multi-phase fault on the LIPA transmission grid, having duration equal to the sum of the normal fault clearing time plus any subsequent post-fault voltage recovery to the final steady-state post-fault voltage. The initial conditions prior to such fault may include outage of any one LIPA transmission element, inclusive of both circuits of a double-circuit line sharing common transmission tower structures.

b) The Resource shall *remain online* for any *voltage disturbance* caused by a single-phase fault on the transmission grid with delayed clearing, plus any subsequent post-fault voltage recovery to the final steady-state post-fault voltage. Clearing time shall be based on the maximum backup clearing time associated with a single point of failure (protection or breaker failure) for any single-phase fault location inclusive of single-phase faults occurring simultaneously on different phases of multi-circuit transmission lines. The initial conditions prior to such fault may include outage of any one LIPA transmission element, inclusive of both circuits of a double-circuit line sharing common transmission tower structures.

c) The Resource shall not be required to *remain on line* for POI low-voltage disturbances where the least *RMS magnitude* of any phase-ground or phase-phase voltage is less than the values specified in Figure 4-1 and Table 4-1 in excess of the cumulative durations shown.

d) The Resource shall not be required to *remain on line* for POI high-voltage disturbances where the greatest *RMS magnitude* of any phase-ground or phase-phase voltage is greater than 1.1 p.u., for a cumulative duration exceeding 1.0 second, or for any fundamental-frequency cycle exceeding 1.2 p.u. of nominal voltage. In addition, if the nominal voltage of the POI is 69 kV or greater, the Resource shall also not be required to *remain on line* for POI voltage in excess of 1.05 p.u. for a cumulative duration exceeding 1800 seconds.

e) The Resource is not required to *remain on line* for transient overvoltages where the instantaneous maximum phase-to-ground or phase-to-phase per-unit voltage, on any phase, exceeds the magnitudes and respective durations specified in Table 4-2. These voltages are the residual voltage with application of appropriate surge protective devices. Figure 4-2 illustrates the interpretation of cumulative instantaneous voltage, which for this example the cumulative duration would be sum of time periods T_1, T_2, and T_3 as shown in the figure.

f) Resources shall ride-through voltage phase angle disturbances in which the phase angle of the fundamental frequency voltage waveform suddenly changes, or “jumps”, by up to 30 electrical degrees in either direction. Resources shall ride through the phase angle jump events described provided the voltage magnitude remains within 0.90 to 1.1 p.u or the voltage magnitude ride through requirements.

g) The Resource shall be required to *remain on line* for any condition not defined as a *voltage disturbance* except where negative-sequence voltages exceed 2% of the nominal voltage for greater than 60 seconds or 5% for greater than 3 seconds.

4.2 Performance During Voltage Disturbance Ride Through

a) The Resource shall inject positive-sequence reactive current (lagging or over-excited for low-voltages and leading or under-excited for over-voltages) during excursions of positive-sequence inverter terminal voltage that fall outside +/- 10% of nominal voltage.

1) Reactive current shall be injected in a smooth manner (without steps or discontinuities with a linear reduction in terminal voltage), where more reactive current is injected for greater voltage excursions.

2) The magnitude of positive-sequence reactive current injection as a function of positive-sequence voltage deviation outside +/-10% shall be adjustable. The Resource shall supply lagging reactive current for positive sequence voltages below 0.90 p.u. and shall supply leading reactive current for positive sequence voltages above 1.10 p.u. The injection of reactive current for abnormal voltages shall be additive to the reactive current flowing from the Resource just prior to the voltage deviation. Furthermore, reactive current injection shall occur in a consistent and continuous manner for smooth transitions between normal and abnormal voltage ranges. The injection of reactive current shall monotonically increase for increasing deviations of positive sequence voltage from 0.9 p.u. for low voltages and 1.1 p.u. for high voltages. During abnormal voltage conditions, the Resource's response time in delivery of 90% of final reactive current for a sudden change in positive sequence voltage shall not be greater than 250 milliseconds.

3) Extremely low voltages: Momentary cessation is allowed for least-phase terminal voltages below 50% of nominal, provided that the resource re-starts current injection within 100 milliseconds of the terminal voltages exceeding 50% of nominal.

b) The Resource shall recover from *voltage disturbances* to the lesser of 90% of its pre-fault active power output or the available primary power (subject to the availability of the primary energy source), at the specified active power recovery rate until the point-of-interconnection positive sequence voltage reaches 0.90 per-unit of the nominal voltage. The active power recovery rate shall be a default of 1 p.u./sec, with an adjustable range of 0.1 – 10 p.u./sec. Active power recovery shall begin no later than 20 msec after the point-of-interconnection voltage reaches 0.90 per-unit of the positive-sequence nominal voltage. For resources capable of net absorption of active power at the POI (i.e., energy storage charging), the active power recovery requirements shall also apply when in an active power absorption mode. The Resource's active power ramp rate recovery settings shall be independently adjustable for active power supply modes and active power absorption modes.

c) The Resource shall *remain on line* and maintain stable operation in the post-fault state for the degraded short-circuit level conditions resulting from any fault condition described in (a) and (b), excluding fault conditions for which the clearing requires complete isolation of the Resource from the LIPA transmission system.

Table 4-1 - Low-Voltage Ride-Through Requirements

Voltage [p.u.]	Cumulative* Maximum Duration [sec]
< 0.25	0.16
< 0.5	1.2
< 0.70	2.5
< 0.9	3

*Note: Cumulative duration is the total duration of the voltage deviation in excess of the severity of the respective voltage magnitude threshold for a single *transmission event*.

Figure 4-1 - Low-voltage ride-through requirements

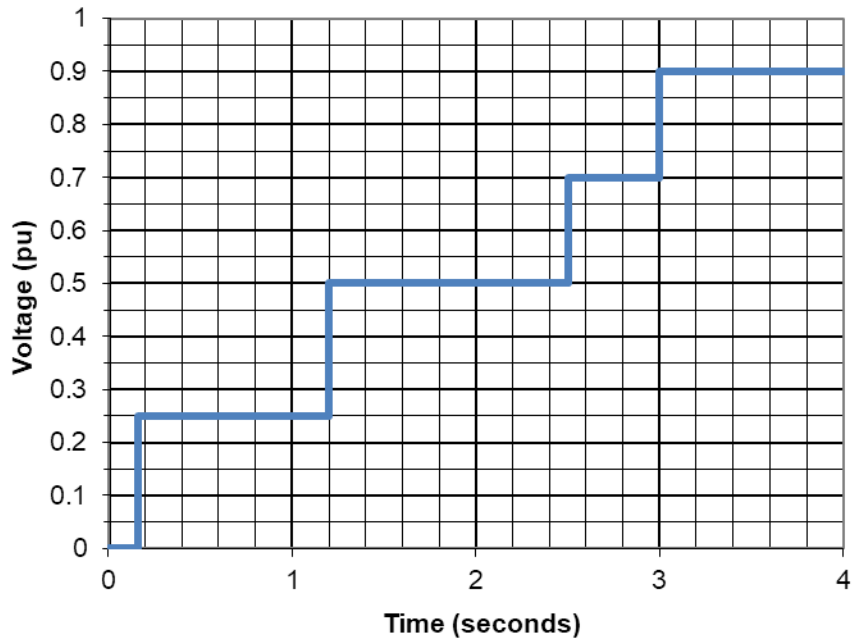
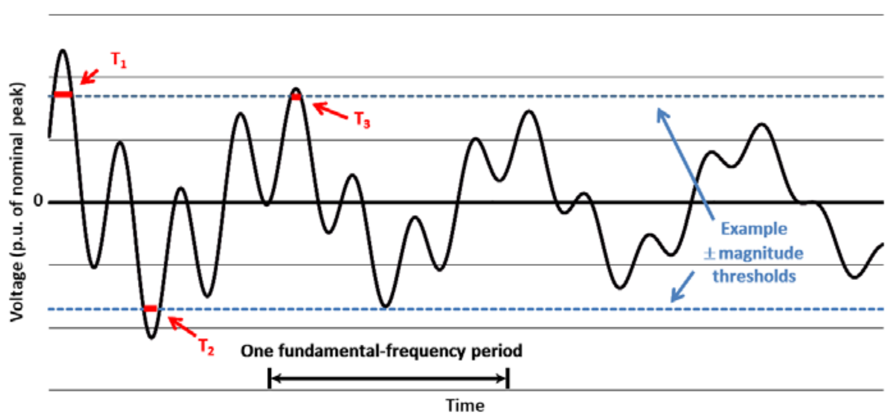


TABLE 4-2 - Transient Over-Voltage Ride-Through Requirements

Voltage [p.u.] (greatest of line-to-line or line-to-neutral)	Cumulative Duration [msec]
V > 1.7	0.2
V > 1.6	1.0
V > 1.4	3.0
V > 1.2	15.0

Figure 4-2 - Illustration of cumulative transient instantaneous voltage duration.



4.3 Frequency Response and Ride Through

a) The Resource shall *remain on line* for all deviations in frequency less severe in magnitude and duration as specified in Table 4-3.

b) For over-frequency events exceeding 60.036 Hz, the active power output of the Resource shall be the lesser of the available active power and a power output limit that decreases at the rate of 0.33 p.u. of the pre-disturbance power level per Hz of frequency deviation above 60.036 Hz.

c) For under-frequency events wherein the frequency is less than 59.964 Hz, the active power of the Resource shall be the lesser of the available active power and a power output limit that increases at the rate of 0.33 p.u. of the pre-disturbance power level per Hz of frequency deviation below 59.964 Hz. Limitations to the under-frequency response due to available active power (e.g., level of solar insolation) and equipment physical limitations shall not be deemed as non-compliant with this requirement.

d) Resources shall ride-through events having a rate-of-change-of-frequency (RoCoF) of up to 5 Hz/sec. Voltage phase jumps, which may be considered to have an infinite RoCoF, are considered separately in Sub-Clause 4.1f.

Table 4-3 - Frequency Ride Through Requirements

Frequency Range (Hz)	Cumulative Duration (seconds)
f > 61.8	may trip
61.8 - 61.2	300 sec
61.2 - 58.8	continuous
58.8 - 57.0	300 sec
f < 57.0	may trip

5. POWER QUALITY IMPACTS

5.1 Rapid Voltage Change

a) With the exception of infrequent energization of power transformers, the Resource shall not cause abrupt changes to the root-mean-squared (rms) voltage magnitude at the POI greater than 0.025 p.u. and that occur at a rate of voltage change not to exceed exceeded 0.025 per unit per second, averaged over a one second period. This requirement applies, non-exclusively, to any de-energization or energization of capacitors, reactors, cables, or transformers (other than on an infrequent basis).

b) Abrupt change in POI *RMS voltage magnitude* due to infrequent power transformer switching shall not exceed 0.1 p.u. for any duration exceeding one cycle of a 60 Hz period, shall not exceed 0.05 p.u. for greater than 0.1 seconds, and shall not exceed 0.025 p.u. for 1.0 seconds.

c) Infrequent energization is defined to include initial project commissioning, return to service following faults or failures in the LIPA or Resource systems, or return to service following maintenance. Transformer energization that occurs on a routine, recurring basis, such as in response to variations in energy resource availability or system dispatch, are expressly excluded from the definition of infrequent energization.

d) With the exception of restoration of operation following LIPA system faults, clearance from System Operations is required prior to any transformer energization producing a change in the *rms magnitude* of the POI voltage exceeding 0.025 p.u. for any duration exceeding one fundamental frequency cycle.

5.2 Repetitious Voltage Variations (Flicker)

Contributions of the Resource to POI voltage variations shall not exceed P_{ST} = 0.35 or P_{LT} = 0.25 as defined in IEEE Std 1453. Variations of generation caused by variations in solar irradiance or wind speed are not considered as causes for flicker, unless the performance of Resource aggravates the voltage changes caused by such variations such as by switching of equipment (e.g., capacitors, generator winding configuration, etc.).

5.3 Harmonic Performance Requirements for Resources Connected to Strong Systems

The requirements of this sub-clause shall apply to Resources connected to the LIPA system where the *nominal short circuit ratio* at the date of initial interconnection to the LIPA system is greater than 20. Resource Owners may opt to comply with Sub-Clause 5.4 in lieu of the requirements stated in this sub-clause.

a) Non-fundamental-frequency current components flowing between the Resource and the LIPA transmission system at any given harmonic order, shall be less than the values specified in Table 5-1. The magnitude of the current at each harmonic order shall be the square root of the sum of the squares of the magnitudes of all current components with frequencies between the frequency of the integer harmonic order minus 30 Hz to plus 30 Hz. The per-unit base is the (rated) current of the Resource when delivering the rated active power at a power factor of 0.95 at nominal voltage. The Total Rated Distortion (TRD) metric is the square root of the difference of the squares of the total *RMS magnitude* of current, inclusive of all fundamental and non-fundamental frequency components) and the *RMS magnitude* of the fundamental frequency component, all in p.u. of the Resource rating. This is indicated in equation form as:

$$.TRD = \sqrt{{I_{RMS}}^2 - {I_{fundamental}}^2}$$

Table 5-1 – Harmonic Current Limits

	Harmonic Order		
	h < 11	11 ≤ h	TRD
Current Limit	2.0%	1.0%	2.5%

b) For resources having an aggregate power rating at a single POI to the LIPA transmission system greater than 20 MW, the IT product of the harmonic components shall be less than 10,000 A. The IT product is defined as follows:

$$IT = \sqrt{\sum_{h=2}^{50} (T_h \cdot I_h)^2}$$

Where:

h = Harmonic order

T_h = TIF weighing factor, as documented in IEEE-519 for the frequency of harmonic order h

I_h = Current injection at harmonic order h.

c) The current distortion specifications are applicable to all frequency components above 120 Hz and less than or equal to 3 kHz. Interpolation of the weighting factors shall be used for non-integer harmonics.

d) Harmonic current limitations specified in this sub-clause apply to the currents caused by the Resource inclusive of harmonic currents caused by background harmonic voltages existing in the LIPA transmission system exclusive of the Resource. The current limitations shall not apply to harmonic current flow that decreases the voltage distortion at the POI, at the same harmonic order as the current.

5.4 Harmonic Performance Requirements for Resources Connected to Weaker Systems

The requirements of this sub-clause shall apply to Resources connected to the LIPA system where the *nominal short circuit ratio* at the date of initial interconnection to the LIPA system is less than or equal to 20. Each of the following requirements shall apply:

a) Interconnection of the Resource shall not cause individual harmonic components or total harmonic distortion (THD_v) of the POI voltage to exceed the values specified in Table 5-2 , inclusive of any harmonic components, not exceeding these limits, present without the Resource connected (ambient distortion). These limitations apply, nonexclusively, to any passive or active amplification or magnification of ambient harmonic distortion. Where the ambient distortion exceeds these limits, the Resource shall not cause any increase in the magnitude of the harmonic voltage components exceeding the limits.

b) The Resource shall not cause an incremental increase in voltage distortion at any non-fundamental order from harmonic orders 2 to 4 or 6 to 50 by greater than 1% of the nominal voltage.

c) The Resource shall not create a fifth harmonic voltage component at the POI, exclusive of ambient distortion, greater than 0.3% of the nominal voltage.

d) The voltage TIF, as defined in IEEE-519, caused by the Resource, shall be less than 25.

e) The IT product of the current across the POI, as defined in Sub-Clause 5.3(b), shall not exceed 10,000 A.

f) The distortion specifications are applicable to all frequency components above 120 Hz and less than or equal to 3 kHz. Interpolation of the weighting factors shall be used for non-integer harmonics.

Table 5-2 – Harmonic Voltage Limits

POI Nominal Voltage	Individual Harmonic	THD_V
≤ 69 kV	3.0%	5.0%
138 kV	1.5%	2.5%
345 kV	1.0%	1.5%

5.5 Radio Frequency Interference

a) The Resource Owner is responsible for any radio frequency interference radiated from the Resource installation or the connection line between the Resource facility and the LIPA POI.

b) The Resource shall not cause radio frequency noise to be radiated from any LIPA transmission line or substation that is of greater intensity than 200 uV/m measured at any point greater than 50' beyond the perimeter of any substation, or 50' from the centerline of any LIPA transmission line. Measurements of radio interference shall be in accordance with IEEE Standard 430-1986 (R1991), and made by instruments compliant with ANSI Standard C63.2-1996.

6. CONTROL PERFORMANCE

6.1 Stability

a) The performance of the Resource shall be stable and without poorly damped oscillations in active or reactive power, exclusive of variations caused by changes in the primary power resource (e.g., solar irradiance), for any system condition yielding a short-circuit capacity at the Resource POI greater than the minimum short-circuit capacity yielded by any N-1-1 outage contingency on the LIPA transmission system.

b) The Resource shall have protections that detect undamped oscillations of the Resource current, having sufficient magnitude to disturb the LIPA system, and to take appropriate action including, nonexclusively, removal of Resource from service (tripping), reduction of control gain, or reduction of power level.

6.2 Control Interactions

a) The Resource shall not engage in or cause adverse or unstable interactions with other controls, including generator excitation controls, capacitor switching controls, and transformer tap changer controls, or other power electronic systems including existing HVDC systems, other dynamic reactive support devices, or other non-synchronous generation resources.

b) Resource Owner shall have primary responsibility to investigate and correct any actual or potential interactions with any other power electronic-based transmission or generation system that is in commissioned service or under construction prior to the date of the commissioning of the proposed Resource.

c) Resource Owner shall be required to cooperate with LIPA, PSEG-LI, and the party responsible for any new power electronic-based transmission or generation system installed or proposed to be installed after the commissioning of the proposed non-synchronous Resource. This cooperation shall include providing parameters and control characteristics necessary to investigate and correct any potential or actual interactions between the systems.

6.3 Changes in Controls

PSEG-LI shall be informed in advance of changes to Resource controls (either parameter changes or software changes to the inverter or plant controller) that can change the dynamic performance of the Resource. PSEG-LI reserves the right to perform studies to determine the impact of such changes. Changes to Resource controls for Resources with a rating greater than 100MW shall not be implemented without PSEG-LI's express approval.

7. TRANSIENT AND TEMPORARY OVERVOLTAGES

a) The Resource shall not cause transient or temporary phase-to-ground or phase-to-phase overvoltages at the POI with cumulative instantaneous magnitudes exceeding the magnitudes and durations specified in Table 7-1. (See Figure 4-2 for illustration of cumulative instantaneous magnitude.)

b) The Resource shall not cause the root-mean-square magnitude of the POI phase-to-phase or phase-to-ground voltage, measured over a 1/60th second window, to exceed 1.2 p.u. of the nominal voltage, or to exceed 1.1 p.u. of the nominal voltage for a period exceeding 1.0 seconds.

c) The Resource shall present an effectively grounded source to the LIPA transmission system.

d) LIPA circuit breakers, including circuit breakers that can potentially isolate the Resource either intentionally or unintentionally, shall not be subjected to interruption with a post-clearing recovery voltage or transient recovery voltage (TRV) in excess of the circuit breaker's rating.

Table 7-1 – Instantaneous Voltage Limits

Instantaneous Voltage Threshold (p.u.)	Maximum Cumulative Duration of Instantaneous Voltage Exceeding Threshold Magnitude (msec)
1.7	1.0
1.6	3.0
1.5	10.0
1.45	50.0
1.4	200.0

8. DOCUMENTATION OF RESOURCE ELECTRICAL CHARACTERISTICS

8.1 Short-Circuit Current Contributions

Resource Owner shall fully describe the current contributions of the proposed Resource to near and remote faults. The short-circuit current contribution characterization shall include:

a) Three-phase, single-phase, phase-to-phase, and double-phase to ground fault types.

b) Characterization of fault current contributions in phase as well as sequence component formats.

c) Indication of the phase angle of the current contribution relative to the residual voltage value at the Resource terminals during the fault.

d) Description of non-fundamental-frequency current components.

e) Dynamic variations in the ac components of current contribution as well as decay of the dc component, if any.

f) Voltage level below which the Resource will cease current injection (e.g., inverter gate blocking).

The recommended format and detail of short-circuit performance data, for varying degrees of fault severity, is provided in Attachment 1 of this document.

8.2 Harmonic Characterization

a) Voltage source converters shall be characterized as Thevenin equivalent models for each of the positive and negative phase sequences for at least the integer harmonics of the fundamental frequency from orders 2 through 50. The Thevenin equivalent shall consist of the source voltage and complex source impedance at each frequency. Where the converter has spectral source components at interharmonic frequencies, the Thevenin equivalents shall be defined for each such frequency. Source data shall be provided for at least 10%, 50%, and 100% of rated active power, or alternatively, the maximum magnitude for each component over the full range of operating power.

b) Line-commutated converters shall be characterized by the currents at each integer harmonic from orders 2 through 50, for the range of active power levels from minimum operating power to rated power in increments no larger than 10% of rated power.

9. REQUIRED DYNAMIC MODELS

Data requirements for system studies is summarized in the NYISO Reliability Analysis Data Manual 24 (i.e. RAD Manual). Data for conducting system planning studies includes the steady state and short circuit network representations, and dynamic model data for performing stability analysis. The NYISO collects this data from all facility owners within the New York Control Area. Resource Owner must develop and maintain data for their facility suitable for performing the steady state, dynamic, and short circuit analyses. The Resource Owner, or prospective Resource Owner (developer) must provide this data to the NYISO in accordance with established NYISO procedures and schedules.

9.1 Positive-Sequence Fundamental-Frequency Model

a) PSEG-LI shall be provided a model, implemented in the Siemens PTI PSS/E dynamic simulation software, formatted for the PSSE version associated with the FERC 715 filing that NYISO is also using, that accurately represents the control characteristics and dynamic behavior of the Resource in response to balanced *voltage* and *frequency disturbances*, to the extent that such can be validly represented in this type of simulation platform (up to 5 Hz bandwidth in the synchronous reference frame). This model shall be provided prior to the Resource being placed into commercial operation.

b) The model shall include all voltage and frequency trip settings implemented in the Resource, inclusive of any indirect tripping on the basis of voltage or frequency that results in the Resource tripping, such as trip settings on essential auxiliary equipment (e.g., coolant pump) for which auxiliary tripping results in tripping of the Resource or curtailment of the Resource active or reactive power capability.

c) Second-Generation Generic Renewable Energy models are permitted, provided they are configured specifically for the plant and are considered reasonably representative of the inverter equipment by the inverter manufacturer. The PSS/E model shall be validated for accurate representation of disturbances that are within the model's appropriate range of application, using a validated electromagnetic transient model or full-scale testing.

d) The PSS/E model shall be fully documented.

e) The PSS/E model must be non-proprietary and shall be accessible to other utilities, system operators, asset owners, and other entities associated with the interconnected transmission network.

f) The PSS/E model shall be updated by the Resource owner prior to any change to the Resource controls or control parameters that materially affects the dynamic performance.

g) The Resource owner shall ensure compatibility of the provided PSS/E model with the version of PSS/E used by PSEG-LI and the NYISO, as well as compatibility of the latest PSS/E version released by Siemens PTI. Upgrades and modification of the models to maintain compatibility with these PSS/E versions shall be the responsibility of the Resource owner.

h) If a user defined model is provided, the Resource Owner shall provide the NYISO and PSEG-LI justification for the use of the user defined model along with the open source code of the model. If for any reason a user defined model open source code cannot be provided, the Resource Owner shall provide the NYISO and PSEG-LI all applicable **.dll files that are usable for the current and future versions of PSS/e used for the creation of dynamics databases. Models and technical documentation (such as the block diagram and user manual) provided by the Resource Owner shall not be confidential or proprietary.

9.2 Electromagnetic Transient Model

a) For a Resource, or an aggregation of Resource units at a single POI, having a maximum active power capacity of 20 MW or greater, PSEG-LI shall be provided an electromagnetic transients model, implemented in the PSCAD simulation software.

b) The simulation model shall be configured for the specific plant application. This model shall be provided to PSEG-LI prior to the Resource being placed into commercial operation. Documentation shall be provided establishing the validity of the model, such as comparisons between model results and full-scale test results for a sufficient range of tests.

c) The PSCAD model may be proprietary, and be bound by reasonable non-disclosure agreements. The model must be made available to LIPA, PSEG-LI, PSEG-LI's agents and consultants, and any other party as directed by PSEG-LI, provided that the party is not in direct competition with the Owner or the Owner's Resource equipment manufacturer.

d) Model documentation shall be provided instructing the user on the setup and configuration of running the model in an accurate manner.

e) The PSCAD model shall be updated by the Owner prior to any change to the Resource's controls or control parameters that materially affects the transient or dynamic performance.

f) In addition, the guidelines for PSCAD models provided in Attachment 2 shall be followed.

ATTACHMENT 1

Short Circuit Performance Tables

Short-Circuit Performance Tables				
Positive Sequence Voltage (pu)	Positive Sequence Current (pu)	Negative Sequence Current (pu)	Positive Sequence Power Factor Angle (deg)	Negative Sequence Power Factor Angle (deg)
One-Cycle Time Frame				
0.9				
0.8				
0.7				
0.6				
0.5				
0.4				
0.3				
0.2				
0.1				
Three-Cycle Time Frame				
0.9				
0.8				
0.7				
0.6				
0.5				
0.4				
0.3				
0.2				
0.1				
Five-Cycle Time Frame				
0.9				
0.8				
0.7				
0.6				
0.5				
0.4				
0.3				
0.2				
0.1				

ATTACHMENT 2

Model Accuracy Features

In order to be sufficiently accurate, the model provided for each facility shall:

Item	Description	Check
1	Represent the full detailed inner control loop of the power electronics. The model cannot use the same approximations classically used in transient stability modeling and should fully represent all fast inner controls, as implemented in the real equipment.	
2	Utilize actual hardware code in creating the PSCAD model *OR* validate the model by comparing the model to measured device response. Validation should be performed for a standard set of disturbances AND include a small signal frequency sweep to confirm the subsynchronous behavior over 5 to 55 Hz. (Beware that models assembled using standard blocks available in the PSCAD master library introduce unacceptable approximations).	
3	Incorporate a full IGBT representation (preferred), or may use a voltage source interface that mimics IGBT switching (i.e. a firing pulse based model). A three phase sinusoidal source representation is not acceptable. It is also recommended to avoid current-source models as these can create numerical instability.	
4	Represent plant level controllers as they are implemented in the real controls, such as automatic voltage regulation. Parameters typically requiring site-specific adjustment should be made user-accessible. For example, the plant level controller should provide access to regulation gains and droop settings.	
5	Represent all pertinent control features as they are implemented in the real controls (e.g. customized PLLs, ride-through controllers, etc.). Incorporate expected site-specific adjustments and settings.	
6	Represent Subsynchronous Oscillation (SSO) mitigation and/or protection including the ability to enable and disable SSO mitigation/protection, if applicable.	

7	Represent shunt capacitor and reactor banks and any dynamic reactive devices. The controls should be modeled if the equipment dynamically responds to a disturbance within 10 seconds. It is recommended to include an initialization routine, even if the controls are not explicitly modeled, so that the capacitor and reactor banks will be at the correct initial operating position at the start of the simulation. For example, if the plant controller would normally place all shunt capacitors in service for 100% dispatch in active power and no shunt capacitors in service for 50% dispatch in active power, then it is recommended that an initialization routine would include this same logic.	
8	Represent all pertinent electrical and mechanical configurations, such as filters and specialized transformers. Mechanical features (such as gearboxes, pitch controllers, etc.) should be included in the model if they impact electrical performance.	
9	Have all pertinent protections modeled in detail. Typically this includes various over-voltage and under-voltage protections (individual phase and RMS), frequency protections, DC bus voltage protections, and overcurrent protection. There may be others.	
10	Accurately reflect behavior throughout the valid (MW and MVAr) output range from minimum power through maximum power. Represent machine slip of Type III (DFIG) wind generation as appropriate for the power dispatch. This value should be calculated and not require manual entry.	

Model Usability Features

In order to allow study engineers to perform system studies and analyze simulation results, the model provided for each facility shall:

11	Have pertinent control or hardware options accessible to the user (e.g. adjustable protection thresholds or active power recovery ramp rates). Diagnostic flags (e.g. flags to show control mode changes or which protection has been activated) should be accessible to facilitate analysis and should clearly identify why a model trips during simulations.	
12	Be capable of accurately running for a time step of 10 µs to 20 µs. Requiring a smaller time step may mean that the control implementation has not used the interpolation features of PSCAD or that inappropriate interfacing between the	

	model and the larger network.	
13	Include documentation and a sample implementation test case. Access to technical support engineers is desirable.	
14	Be capable of initializing itself. Models shall initialize and ramp to full output within without external input from simulation engineers.	
15	Accept external reference values. This includes active and reactive power reference values (for Q control modes), or voltage reference values (for V control modes).	
16	Allow protection models to be disabled. Many studies result in inadvertent tripping of converter equipment, and the ability to disable protection functions temporarily provides study engineers with valuable system diagnostic information.	
17	Allow the active power capacity of the model to be scaled. This is distinct from a dispatchable power order, and is used for modeling different plant capacities (e.g. if a portion of the plant is offline).	

Model Efficiency Features

In order to improve study efficiency and model compatibility the following efficiency features are requested. Note that no feature should compromise model accuracy.

18	Be compiled using Intel Fortran compiler version 9 or higher and capable of running in Intel Fortran version 12. Ideally, the model should not be dependent on a specific Fortran version to run.	
19	Use PSCAD version 4.5.3 or higher. The model should not be dependent on a specific PSCAD version to run.	
20	Initialize as quickly as possible (under 5 seconds; one second is ideal) to user supplied terminal conditions.	
21	Support multiple instances of its own definition in the same simulation case.	
22	Support the PSCAD “snapshot” feature.	

23	Support the PSCAD “multiple run” feature.	
24	Allow replication in different PSCAD cases or libraries through the “copy” or “copy transfer” features.	