Long Island Power Authority

Statement of Performance Requirements for Transmission-Connected Resources Using Non-Synchronous Generation

PERFORMANCE REQUIREMENTS FOR TRANSMISSION-CONNECTED RESOURCES USING NON-SYNCHRONOUS GENERATION

1.0 SCOPE

The technical requirements in this statement shall apply to all generation resources offered in response to the Fuel Cell Feed-in Tariff program 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 statement is not applicable to transmission-connected resources using synchronous generators nor is it applicable to resources connected to the LIPA distribution systems.

2.0 REACTIVE POWER CAPABILITY AND CONTROL

2.1 Reactive Power Capability in Normal Operation

a. The Resource shall have the capability of delivering reactive power to the LIPA transmission system (lagging, or over-excited operation) at the point of interconnection that is at least 33% of the Resource's stated maximum real power capacity, when the voltage at the point of interconnection is at the nominal magnitude, at all levels of real power output in excess of 20% of the Resource's rated capacity.
b. The Resource shall have the capability to absorb reactive power from the LIPA transmission system (leading, or under-excited operation) at the point of interconnection that is at least 33% of the Resource's stated maximum real power capacity, when the voltage at the point of interconnection is at the nominal magnitude, at all levels of real power output in excess of 20% of the Resource's rated capacity.
c. At power output levels less than or equal to 20% of the Resource's stated maximum real power capacity, the Resource shall be capable of a net power factor at the point of interconnection between 0.518 leading to 0.518 lagging.
d. Reactive power capability requirements, as a percentage of the reactive power capability requirements at nominal voltage, are specified in Figure 2-1 for off-nominal voltages within the normal operating voltage range.
e. Real power delivery by the Resource, as specified in 2.1(a through d), shall not be limited or constrained by the delivery or absorption of reactive power when voltage

at the Point of Interconnection is within the normal range of 0.95 to 1.05 per-unit of the nominal voltage.

f. The reactive power delivered shall be continuously variable over the specified reactive power range.

g. 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.

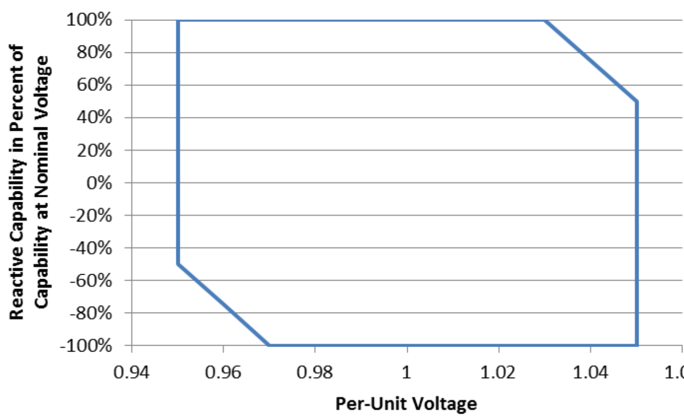

Figure 2-1 *Required reactive capability as function of point of interconnection bus voltage. Positive percentage indicates overexcited (lagging) reactive power, negative percentage indicates under-excited (leading) reactive power.*

2.2 Reactive Power Capability during Undervoltage Conditions

a. The Resource shall have the capability to deliver reactive current to the LIPA transmission system (lagging, or overexcited operation) at the point of interconnection that is at least 33% of the Resource's output current rating at nominal voltage when the positive-sequence voltage at the point of interconnection is less than 0.95 p.u., and greater than 0.5 p.u., of the nominal voltage.

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

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

2.3 Reactive Power Control Capability

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 Point of Interconnection, regardless of whether the Resource is composed of a single generation unit, or a multiplicity of individual generation units.

2.3.1 Constant Reactive Power Mode

a. In the constant reactive power mode, the net reactive power at the Point of Interconnection 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 2.1 of this Statement.
b. The steady-state reactive power flow into or out of the LIPA system at the Point of Interconnection 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 2.1 of this Statement, within tolerances of +/- 2% of the Resource's real power rating.
c. Transient changes of voltage, for which the initial and final phase voltage magnitudes are within the normal range of operation (0.95 p.u. to 1.05 p.u. of nominal), and any changes of the Resource's real power generation, shall not cause the net reactive power at the Point of Interconnection to vary outside of the specified steady-state reactive power tolerances for a duration in excess of 0.5 seconds.

2.3.2 Constant Power Factor Mode

a. In the constant power factor mode, the net reactive power at the Point of Interconnection shall be automatically varied in proportion to the real 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 Point of Interconnection 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 2.1 of this Statement, within tolerances of +/- 2% of the Resource's real power rating.
c. Transient changes of voltage, for which the initial and final phase voltage magnitudes are within the normal range of operation (0.95 p.u. to 1.05 p.u. of nominal), and any changes of the Resource's real power generation, shall not cause the net power factor to deviate from the specified steady-state tolerances for a duration in excess of 0.5 seconds.

2.3.3 Voltage Regulation Mode (with Droop)

a. In the voltage regulation mode, the reactive power of the Resource shall be automatically varied to regulate the Point of Interconnection 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 0.04 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 real power capacity of the Resource.
e. The Resource shall not be required to provide reactive power greater than as specified in Sub-Clause 2.1 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 point of interconnection 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 0.1 second closed-loop response time under nominal system short-circuit level conditions. Response time is defined as the time from when a step stimulus is initiated (step in voltage regulation setpoint or switching of an external reactive device such as to cause a step change in the voltage) until the Resource reactive output has reached 90% of its final value.
h. For a step change in the voltage regulation setpoint, the resulting voltage response shall not overshoot the final value by more than 10% of the change in steady-state voltages before and following the step.

2.3.4 Dispatch of Reactive 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 implemented within ten (10) minutes of issuance of the order by PSEG-LI System Operations.

3.0 VOLTAGE AND FREQUENCY DISTURBANCE PERFORMANCE

a. In order to minimize power resource deficiencies in the LIPA system as a result of system voltage and frequency disturbances, which may affect multiple power generation resource facilities simultaneously, ride-through performance requirements are set forth in this clause.
b. The term "remain on line" is used in this clause, and is defined to mean that the Resource retains the ability to maintain real and reactive power output or immediately recover real and reactive power output as specified in this Clause.

3.1 Low-Voltage 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 lesser 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 recover to 90% of its pre-fault current output within 150 ms of the recovery of the point of interconnection positive sequence voltage to 0.85 per-unit of the nominal voltage.
d. The Resource shall recover to the lesser of its pre-fault real power output or the available primary power, within 250 ms of the recovery of the point-of-interconnection positive sequence voltage to 0.95 per-unit of the nominal voltage, subject to the availability of the primary energy source.
e. The Resource shall remain online 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.
f. The Resource shall not be required to remain online for system low-voltage disturbances creating a positive-sequence voltage component less than specified in Figure 3-1 for the cumulative durations shown, nor shall it be required to remain online for unbalanced system voltage disturbances creating a negative-sequence voltage greater than specified in Figure 3-2 for the cumulative durations shown.

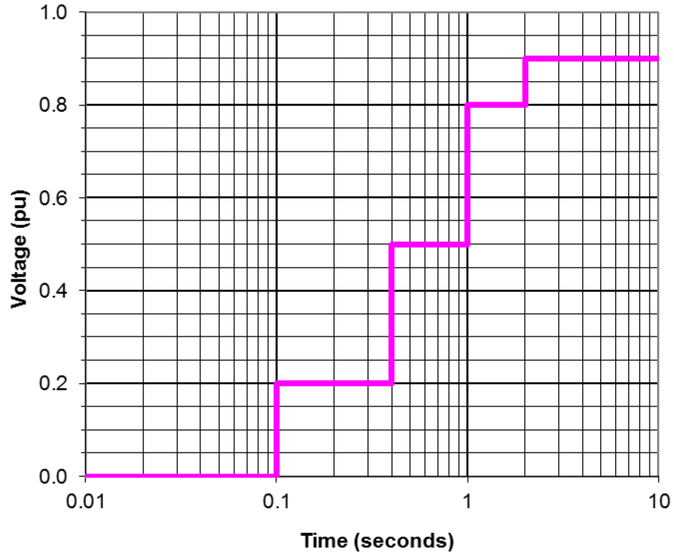

Figure 3-1 Minimum positive-sequence voltage ride through requirement.

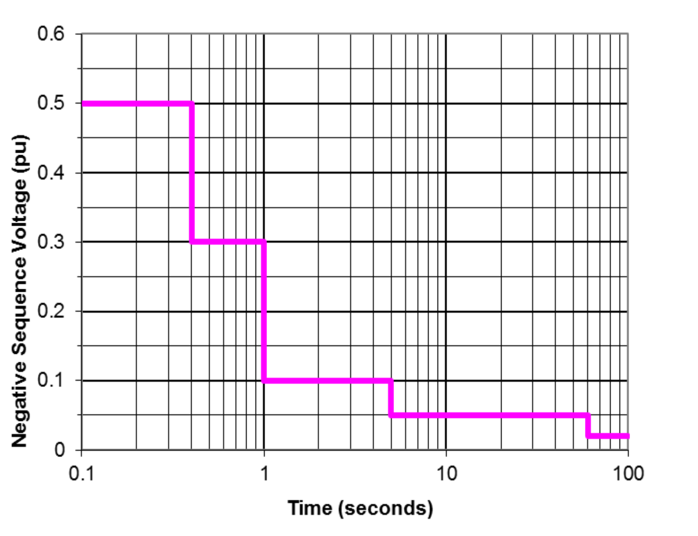

Figure 3-2 Maximum negative-sequence voltage ride through requirement.

3.2 High-Voltage Ride Through

The Resource shall remain on line for temporary overvoltages where the maximum phase-to-ground or phase-to-phase per-unit voltage, on any phase, is no greater than the magnitudes and durations specified in Figure 3-3, and which do not result in a negative-sequence component of voltage greater in magnitude and duration than specified in Figure 3-2.

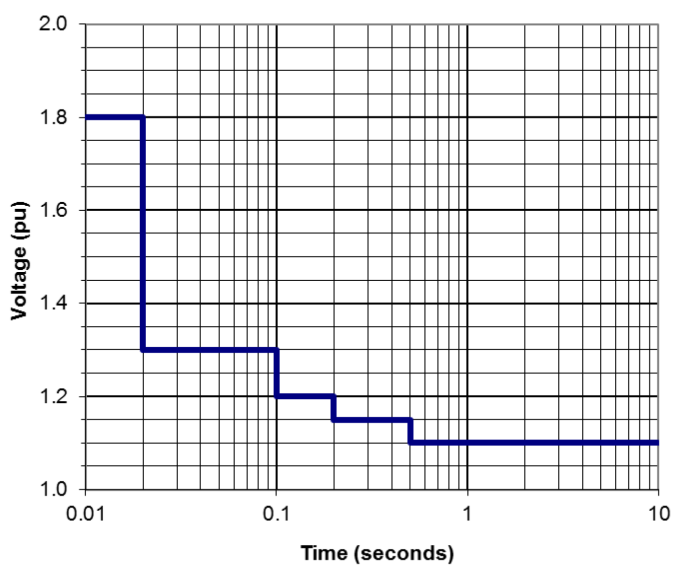

Figure 3-2 Maximum high voltage ride through requirement.

3.3 Voltage Disturbances within the Normal Magnitude Range

a. Resources shall remain online for all deviations in voltage magnitude or relative phase angle that do not cause any phase voltage to be outside of the normal voltage range of 0.95 p.u. to 1.05 p.u. of nominal, and which do not cause a negative sequence component of voltage exceeding the magnitudes and durations specified in Figure 3-2.

b. For all voltage disturbances within the normal magnitude range, as specified in (a), the real power output of the Resource shall not deviate more than 10% from the pre-disturbance real power level for greater than 100 ms, and shall not deviate more than 2% from the pre-disturbance real power level for greater than 500 ms, as a direct result of the voltage disturbance. This requirement does not limit power variations due to availability of the primary energy source (e.g., a change in solar irradiance) that is not related to the voltage disturbance.

3.4 Frequency Response and Ride Through

a. The Resource shall remain online for all deviations in frequency less severe in magnitude and duration as specified in Figure 3-3.

b. For over-frequency events exceeding 60.036 Hz, the real power output of the Resource shall be the lesser of the available real 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 real power of the Resource shall be the lesser of the available real 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 real power (e.g., level of solar insolation) and equipment physical limitations shall not be deemed as non-compliance with this requirement.

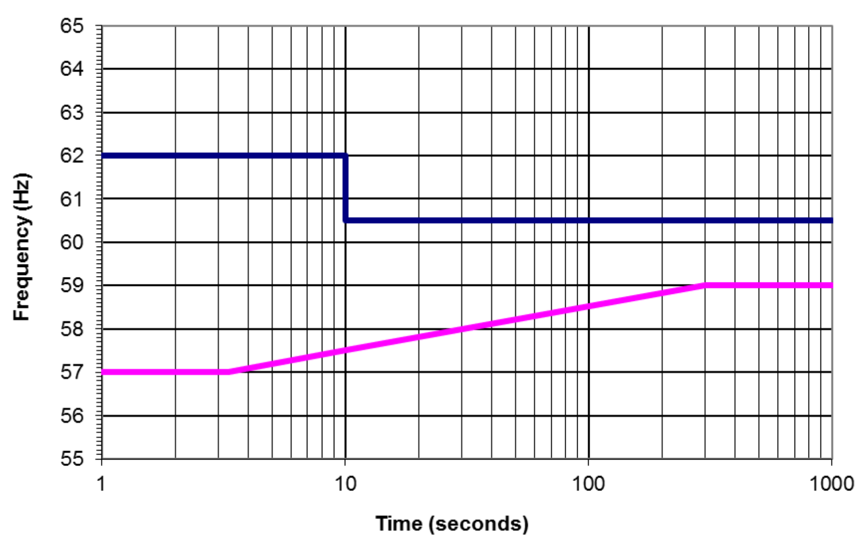

Figure 3-3 *Frequency ride-through range.*

4.0 HARMONIC AND INTERFERENCE PERFORMANCE

4.1 Harmonic Current Limits

a. Non-fundamental-frequency current components, at any given frequency, injected into the LIPA transmission system by the Resource shall be less than the values specified in Table 4-1. The per-unit base is the (rated) current of the Resource when delivering the rated maximum real power at a power factor of 0.95 at nominal voltage. The RSS metric is the square root of the sum of the squares of the individual current frequency components from harmonic orders 2 to 50.

Table 4-1 – Harmonic Current Limits

	Harmonic Order				
	h < 17	17 ≤ h < 23	23 ≤ h < 35	35 ≤ h	RSS
Current Limit	2.0%	1.5%	0.6%	0.3%	3.0%

b. For resources having an aggregate power rating at a single point of interconnection 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:

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

Where:

h	=	Harmonic order
T_h	=	TIF weighting 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, not inclusive of harmonic currents caused by background harmonic voltages existing in the LIPA transmission system exclusive of the Resource.

e. Interharmonics shall be evaluated with respect to the limits applicable to the nearest integer harmonic.

4.2 Harmonic Voltage Limits

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

b. The voltage TIF, as defined in IEEE-519, caused by the Resource, shall be less than 25.
c. The voltage 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. These voltage distortion limitations apply to active contribution by the Resource, and exclusive of voltage distortion amplification caused by resonances of passive circuit components.

4.3 Power Line Carrier Interference

a. Power line carrier (PLC) systems are used for protection communications on the LIPA transmission system. The communication channels are in the frequency range of 30 kHz to 500 kHz. Harmonic and electrical noise conducted or radiated from the Resource system shall not interfere with any LIPA power line carrier (PLC) system.
b. In addition to potential interference due to noise injected in the PLC channel frequency range, experience with prior power electronic systems shows the possibility of PLC receiver input overload due to energy in the 4 kHz to 10 kHz frequency range due to PLC receiver input stage overload due to energy outside of the carrier frequency range. The contribution of harmonics and electrical noise injected into the LIPA system by the Resource shall not result in voltage across the drain coils of any LIPA PLC coupling capacitors greater than 5% of their design maximum.

4.4 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 point of interconnection.
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.

5.0 CONTROL PERFORMANCE

5.1 Stability

The performance of the Resource shall be stable and without poorly damped oscillations in real 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 point of interconnection greater than the minimum short-circuit capacity yielded by any N-1-1 outage contingency on the LIPA transmission system.

5.2 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. Respondent 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 ESS. This cooperation shall include providing parameters and control characteristics necessary to investigate and correct any potential or actual interactions between the systems.

6.0 TRANSIENT AND TEMPORARY OVERVOLTAGES

a. The Resource shall not cause transient or temporary overvoltages at any point on the LIPA system more severe than the overvoltage envelope defined in Figure 6-1. The temporary voltage envelope for a given bus is defined as the plot of voltage versus time, for which the voltage value at any instant of time is the maximum instantaneous p.u. value of any phase-to-ground or phase-to-phase voltage magnitude (absolute value) during the preceding 16.6666 milliseconds. Overvoltage duration is defined as the total cumulative period of time that the TOV envelope is at or above the given magnitude as a result of a single initiating event.
b. The Resource shall present an effectively grounded source to the LIPA transmission system.
c. Isolation of the Resource shall not cause result in recovery voltages across any LIPA circuit breaker establishing the isolation, in excess of that circuit breaker’s transient recovery voltage (TRV) or voltage rating.

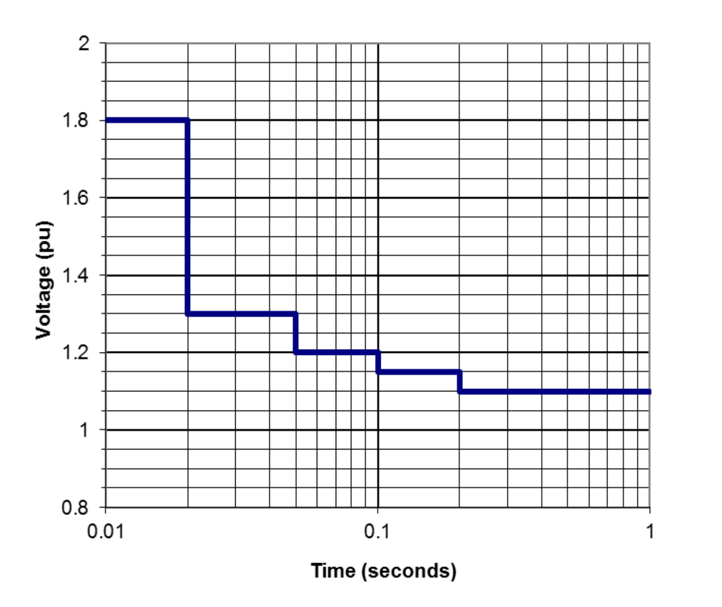

Figure 6-1 Limits to overvoltage caused by Resource

7.0 SHORT-CIRCUIT CONTRIBUTIONS

a. Respondents shall fully describe the current contributions of the proposed Resource to near and remote faults. The short-circuit current contribution characterization shall include:
   i. Three-phase, single-phase, phase-to-phase, and double-phase to ground fault types.
   ii. Characterization of fault current contributions in phase as well as sequence component formats.
   iii. Indication of the phase angle of the current contribution relative to the residual voltage value at the Resource terminals during the fault.
   iv. Description of non-fundamental-frequency current components.
   v. Dynamic variations in the ac components of current contribution as well as decay of the dc component, if any.

b. PSEG-LI shall assess whether the short-circuit contribution of any Resource is responsible for total fault currents in excess of the rating of any LIPA system circuit breaker or other component. The costs of upgrading any such equipment subject to excessive duty due to the Resource will be included in the evaluation of Resource proposals.

8.0 REQUIRED DYNAMIC MODELS

8.1 Positive-Sequence Fundamental-Frequency Model

a. PSEG-LI shall be provided a model, implemented in the Siemens PTI PSS/E dynamic simulation software, Version 32.1.1, 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. A fully detailed model is required and a general model is not acceptable.
c. 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, 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.

8.2 Electromagnetic Transient Model

a. For a Resource, or an aggregation of Resource units at a single point of interconnection, having a maximum real power capacity of 50 MW or greater, PSEG-LI shall be provided an electromagnetic transients model, implemented in the PSCAD simulation software, Version 4.2 or later, that accurately represents the control characteristics and dynamic behavior of the Resource in response to balanced and unbalanced voltage, phase, and frequency disturbances with up to a 1 kHz bandwidth of simulation validity. This model shall be provided to PSEG-LI prior to the Resource being placed into commercial operation.
b. The PSCAD model shall use the same power converter control software algorithms as used in the actual equipment, or a fully validated approximation of these controls that provides modeling fidelity across the specified simulation validity bandwidth.
c. An averaged power converter model may be substituted for a full switching model, provided the averaged model provides valid representation over the specified bandwidth and represents the interactions across the converter, between the ac and dc sides.
d. 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.
e. 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 Respondent or the Respondent's Resource equipment manufacturer.

f. The PSCAD model may be provided in a compiled, "black box" form such that the details of the model are not disclosed. Information needed to utilize the model, however, must be adequately documented.
g. Information needed to utilize the model shall be fully documented.
h. The PSCAD model shall be updated by the Respondent prior to any change to the ESS controls or control parameters that materially affects the transient or dynamic performance.
i. The Respondent shall ensure compatibility of the provided PSCAD model with the version of PSCAD specified by PSEG-LI. Upgrades and modification of the models to maintain compatibility with new PSCAD versions shall be the responsibility of the Respondent.