MINIMUM TECHNICAL REQUIREMENTS FOR INTERCONNECTION OF PHOTOVOLTAIC (PV) FACILITIES

The Seller shall comply with the following minimum technical requirements:

1. VOLTAGE RIDE-THROUGH:

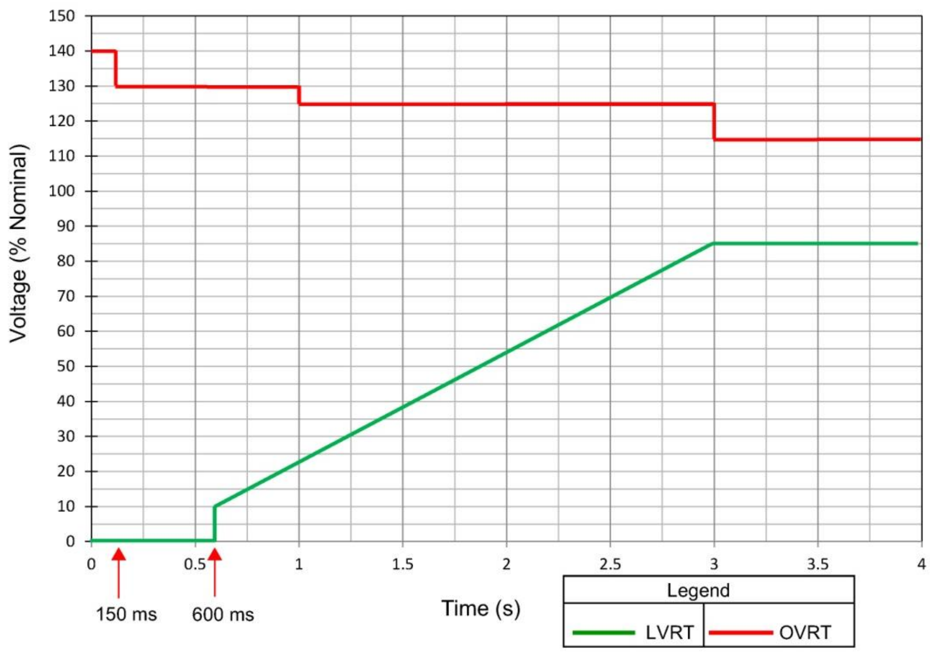

Figure 1 Voltage Ride-Through Requirements

a. PREPA's Low Voltage Ride-Through (LVRT) Requirements:

i. From Figure 1, PREPA requires all generation to remain online and be able to ride-through three phase and single phase faults down to 0.0 per-unit (measured at the point of interconnection), for up to 600 ms.

ii. All generation remains online and operating during and after normally cleared faults on the point of interconnection.

iii. All generation remains online and operating during backup-cleared faults on the point of interconnection.

iv. During the low voltage fault conditions, the PV facility shall operate on reactive current injection mode. This mode of operation shall be implemented with a reactive current droop characteristic which shall have an adjustable slope from 1 to 5%. A dead band of 15 % is required.

b. PREPA's Overvoltage Ride-Through (OVRT) Requirements:

i. PREPA requires all generation to remain online and able to ride-through symmetrical and asymmetrical overvoltage conditions specified by the following values illustrated in Figure 1:

Overvoltage (pu)	Minimum time to remain online
1.4 – 1.3	150 ms
1.3 – 1.25	1 s
1.25 – 1.15	3 s
1.15 or lower	indefinitely

2. Voltage Regulation System (VRS)

Constant voltage control shall be required. Photovoltaic System technologies in combination with Static Var Controls, such as Static Var Compensators (SVCs) and STATCOMs are acceptable options to comply with this requirement. A complete and detailed description of the VRS control strategy shall be submitted for evaluation.

a) Photovoltaic Facilities (PVF) must have a continuously-variable, continuously-acting, closed loop control VRS; i.e. an equivalent to the Automatic Voltage Regulator in conventional machines.

b) The VRS set-point shall be adjustable between 95% to 105% of rated voltage at the Interconnection Facility (connection to PREPA TC, sectionalizer). The VRS set-point must also be adjustable by PREPA's Energy Control Center via SCADA.

c) The voltage regulation at the Interconnection Facility (connection to PREPA TC or sectionalizer) shall be based in direct measurement of the Interconnection Facility (connection to PREPA TC or sectionalizer) voltage. Line drop compensation or similar strategies shall not be permitted.

d) The VRS shall operate only in a voltage set point control mode. Controllers such as Power Factor or constant VAR are not permitted.

e) The VRS controller regulation strategy shall be based on proportional plus integral (PI) control actions with parallel reactive droop compensation. The VRS Droop shall be adjustable from 0 to 10%.

f) At zero percent (0%) droop, the VRS shall achieve a steady-state voltage regulation accuracy of +/- 0.5% of the controlled voltage at the Interconnection Facility (connection to PREPA TC or sectionalizer).

g) The VRS shall be calibrated such that a change in reactive power will achieve 95% of its final value no later than 1 second following a step change in voltage. The change in reactive power should not cause excessive voltage excursions or overshoot. If a voltage overshoot is generated during a change in reactive power its value shall be less than 1%.

h) The generator facility VRS must be in service at any time the PVF is electrically connected to the grid regardless of MW output from the PVF.

i) The VRS dead band shall not exceed 0.1%.

3. Reactive Power Capability and Minimum Power Factor Requirements

The total power factor range shall be from 0.85 lagging to 0.85 leading at the Interconnection Facility (connection to PREPA TC or sectionalizer). The reactive power requirements are necessary to provide support to the system operation based on the voltage profile and reactive power needs. . The intent is that a PVF can ramp the reactive power from 0.85 lagging to 0.85 leading in a smooth continuous fashion at the Interconnection Facility (connection to PREPA TC or sectionalizer).

The +/- 0.85 power factor range should be dynamic and continuous at the Interconnection Facility (connection to PREPA TC or sectionalizer). This means that the PVF has to be able to respond to power system voltage fluctuations by continuously varying the reactive output of the plant within the specified limits. The previously established power factor dynamic range could be expanded if studies indicate that additional continuous, dynamic compensation is required. It is required that the PVF reactive capability meets +/- 0.85 Power Factor (PF) range based on the PVF Aggregated MW Output, which is the maximum MVAr capability corresponding to maximum MW Output. It is understood that positive (+) PF is where the PVF is producing MVAr and negative (-) PF is where the PVF is absorbing MVAr.

This requirement of MVAr capability at maximum output shall be sustained throughout the complete range of operation of the PVF as established by Figure 2. The MVAr capability shall also be sustained throughout the complete Interconnection Facility (connection to PREPA TC or sectionalizer) voltage regulation range (95% to 105% of rated voltage at the Interconnection Facility).

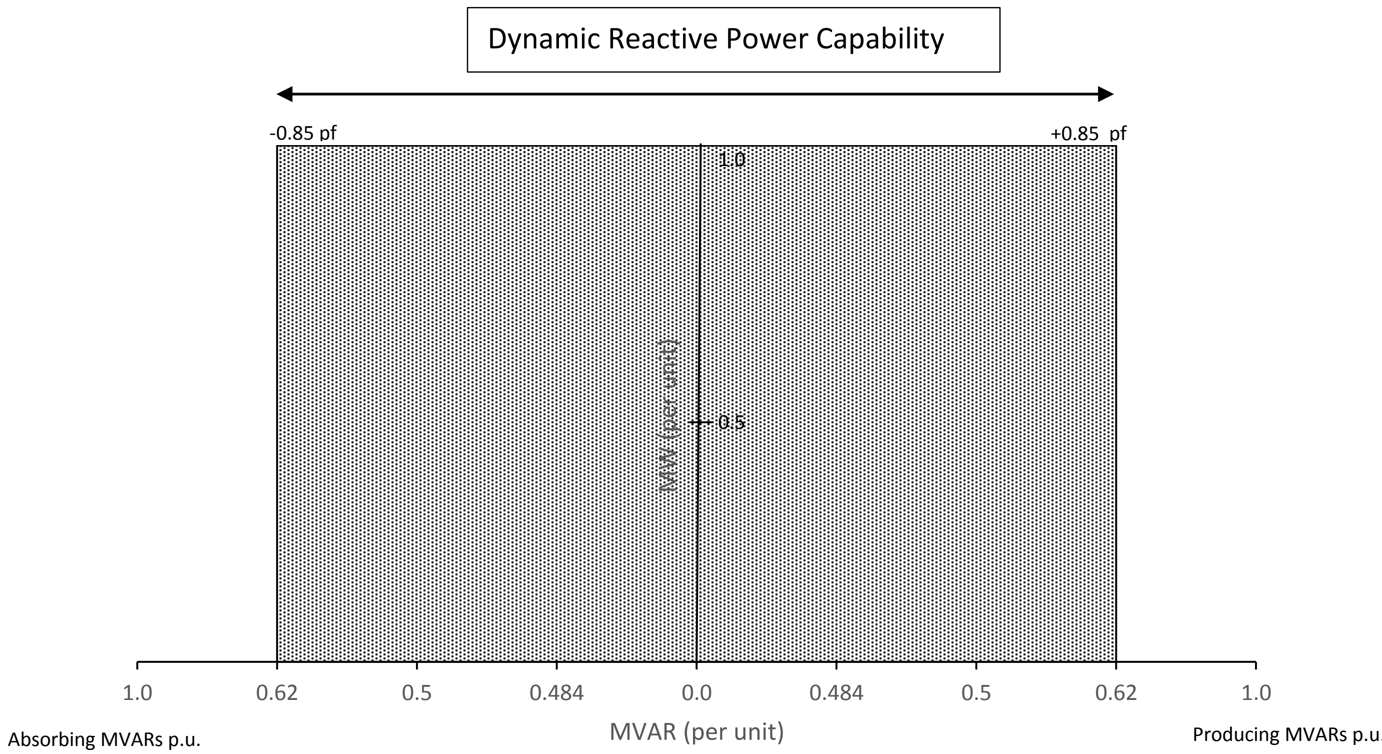

Figure 2 Reactive Power Capability Curve

4. Short Circuit Ratio (SCR) Requirements:

Short Circuit Ratio values (System Short Circuit MVA at POI/PV Facility MVA Capacity) under 5 shall not be permitted. The Seller shall be responsible for the installation of additional equipment, such as synchronous condensers, and controls necessary to comply with PREPA's minimum short circuit requirements.

5. Frequency Ride Through (FRT):

- 57.5 - 61.5 Hz No tripping (continuous)
- 61.5 - 62.5 Hz 30 sec
- 56.5 - 57.5 Hz 10 sec
- < 56.5 or > 62.5 Hz Instantaneous trip

6. Frequency Response/Regulation:

PV facility shall provide an immediate real power primary frequency response, proportional to frequency deviations from scheduled frequency, similar to governor response. The rate of real power response to frequency deviations shall be similar to or more responsive than the droop characteristic of 3-5% range used by conventional generators. PV facility shall have controls that provide both for down-regulation and up-regulation. PV technologies, in combination with energy storage systems such as, but not limited to battery energy storage systems (BESS), and flywheels are acceptable options to comply with PREPA's frequency response and regulation requirements.

The PV facility response shall be proportional to the frequency deviation, based on the specified 3-5% range droop characteristic. The droop shall be configurable from 3% to 5% in steps of 0.5% (3.0%, 3.5%, 4.0%, 4.5%, 5%).The frequency response dead band shall not exceed 0.02%. For large frequency deviations (for example in excess of 0.3 Hz), the PV facility shall provide an immediate real power primary frequency response of at least 10% of the maximum AC active power capacity (established in the contract). The time response (full 10% frequency response) shall be less than 1 second. Frequency response shall not be limited by, and shall be decoupled from, the ramp rate control. The frequency response of the facility shall be continuously in operation, even during ramp rate events. After the two decoupled functions are added together, the facility shall be able to simultaneously comply with both requirements.

If energy storage systems are utilized to comply with the frequency regulation requirements, and during a disturbance the system frequency stays below 59.7 Hz, the facility frequency response shall be maintained for at least 9 minutes. After the ninth minute the real power primary frequency response shall not decrease at a ramp rate higher than 10% of the maximum AC active power capacity per minute. The energy storage systems utilized to comply with the frequency regulation requirement shall be designed based on a storage capacity equivalent to at least 9.5 minutes of the 10 % AC contracted capacity measured at the Interconnection Facility (connection to PREPA TC or sectionalizer) for downward frequency events, and a similar amount for upward frequency events. This represents an equivalent of 9 minutes full participation, plus one minute ramp down complying with the ramp rate requirement. This energy will be used on a continuous basis for regulation against frequency deviations. During periods of time were the energy storage system utilized to comply with the frequency regulation requirement is completely charged (cannot absorb more power), the PV inverters will assume the responsibility of the upward frequency events. If the energy available for frequency regulation is drained, the function shall be restored in a time period less than 10 minutes and with at least 95% of the energy capacity restored. The energy charging process shall not affect the ramp rate control requirement or the frequency regulation of the grid.

The operational range of the frequency response and regulation system shall be from 10% to 110% of the maximum AC active power capacity (established in the contract). The PV facility power output at the Interconnection Facility (connection to PREPA TC or sectionalizer) shall not exceed the maximum AC active power (established in the contract) except to comply with the frequency response requirement.

7. Ramp Rate Control:

Ramp Rate Control is required to smoothly transition from one output level to another. The PV facility shall be able to control the rate of change of power output during some circumstances, including but not limited to: (1) rate of increase of power; (2) rate of decrease of power; (3) rate of increase of power when a curtailment of power output is released; and (4) rate of decrease in power when curtailment limit is engaged. A 10 % per minute (0.1667 % per second) rate (based on AC contracted capacity) limitation shall be enforced. This ramp rate limit applies both to the increase and decrease of power output and is independent of meteorological conditions. The ramp rate control tolerance shall be +10%.

The energy storage system utilized to comply with the ramp rate control requirement shall be designed based on a minimum storage capacity equivalent to 25 minutes of the 30 % AC contracted capacity measured at the Interconnection Facility (connection to PREPA TC or sectionalizer). The minimum nominal power output capacity of the energy storage system utilized to comply with the ramp rate control requirement shall be 30% of AC contracted capacity measured at Interconnection Facility (connection to PREPA TC or sectionalizer); and for at least one (1) minute, a minimum effective power output capacity of 45% of AC contracted capacity measured at the Interconnection Facility (connection to PREPA TC or sectionalizer). The transition from effective power output capacity to nominal power output capacity shall not exceed the ramp rate requirement of 10% per minute.

The Frequency Response/Regulation and Ramp Rate Control functions shall be decoupled, continuously in operation and the facility shall be able to comply simultaneously with both requirements, while the PV facility is generating and injecting power to the grid. This means that the energy storage system shall include, as a minimum: 10% of the contracted capacity for Frequency Response/Regulation for at least 9.5 minutes (see section 6 for details) and 30% of contracted capacity for Ramp Rate Control for at least 25 minutes. The energy storage system shall also be able to provide a minimum effective capacity of 45% of the contracted capacity for at least one (1) minute at the Interconnection Facility (connection to PREPA TC or sectionalizer). Therefore, the minimum acceptable capacity for the energy storage system is a total combined size of 40% of contracted capacity, and for at least one (1) minute, the system has to have an effective capacity of 45% of the contracted capacity.

Rates of change in active power at the PV facility's Interconnection Facility (connection to PREPA TC or sectionalizer) in excess of the 10 % per minute rate requirement caused by the loss of generating resource (solar irradiance) that require more than the minimum storage capacity defined in this MTRs document, will not be considered in non-compliance with the ramp rate control requirement. Therefore, if the ramp is controlled within the limits specified in the requirement, or if the storage system cannot control the ramp rate because it is outside of its minimum required capabilities, but performs as specified, the PV facility will not be considered in non-compliance. However, if the energy storage system cannot control the ramp rate as required because does not perform according to at least with the minimum required capabilities specified in this MTRs document , the PV facility will be considered in non-compliance.

8. AUTO-CURTAILMENT

The Seller shall implement an auto-curtailment strategy for the PV facility to address and compensate deficiencies that can affect the facility compliance with the MTRs. Some of the conditions to apply auto-curtailment are:

a. A reduction on the reactive power capacity of the facility (by example due to inverters out of service, any other condition that can reduce the required reactive power capacity of the facility).

b. A reduction in the active power capacity of the storage system (by example loss of some of the battery strings, a BESS inverter out of service, any other condition that can reduce the required active power capacity of the energy storage system)

c. Loss of the Interconnection Facility (connection to PREPA TC or sectionalizer) readings used for the different controls (voltage, frequency, ramp, etc.) of the facility. This can happen due to a malfunction of the equipment used for the Interconnection Facility (connection to PREPA TC or sectionalizer) readings. In this case the curtailment should be to zero.

d. A fault in the Voltage Control, Frequency Response Control, Ramp Rate Control. In this case the facility should be curtailed to zero output.

e. Any other condition not mentioned here but that based in the facility design can cause a non-compliance with the MTRs.

A complete and detailed description of the auto-curtailment strategy shall be submitted for evaluation.

9. Power Quality Requirements:

The Seller shall address, in the design of their facilities potential sources and mitigation of power quality degradation prior to interconnection. Design considerations should include applicable standards including, but not limited to IEEE Standards 142, 519, 1100, 1159, and ANSI C84.1. Typical forms of power quality degradation include, but are not limited to voltage regulation, voltage unbalance, harmonic distortion, flicker, voltage sags/interruptions and transients.

10. Power Management

PV facility shall provide adequate technology (communicating technology and the corresponding control equipment) and implement power management requirements (ramp rate limits, output limits, curtailment) as established by PREPA.

11. Special Protection Schemes:

PV facility shall provide adequate technology and implement special protection schemes as established by PREPA in coordination with power management requirements.

12. General Interconnection Substation Configuration:

An interconnecting generation producer must interconnect at an existing PREPA switchyard , unless otherwise approved by PREPA in the contract. The configuration requirements of the interconnection depend on where the physical interconnection is to occur and the performance of the system with the proposed interconnection. The interconnection must conform, at a minimum, to the original designed configuration of the switchyard. PREPA, at its sole discretion, may consider different configurations due to physical limitations at the site.

13. Modeling and Validation

Once final adjustments and parameter settings related with commissioning and MTR compliance tests are completed, the Seller shall submit a PSS/e Siemens – PTI Certified mathematical model and validation report.

When referred to the mathematical model, this shall include but is not limited to PV inverters, transformers, collector systems, plant controllers, control systems and any other equipment necessary to properly model the PV facility for both steady-state and dynamic simulation modules.

The Seller shall be required to submit user manuals for both the PV inverter and the PV facility models including a complete and detailed description of the voltage regulation system (VRS) and frequency regulation system model implementation. The mathematical models shall be fully compatible with the latest and future versions of PSS/E. It is preferred that the models are PSS/E standard models. In the case that the Seller submits user written models, the Seller shall be required to keep these models current with the future versions of the PSS/E program until such time that PSS/E has implemented a standard model. The Seller shall submit to PREPA an official report from Siemens - PTI that validates and certifies the required mathematical models, including subsequent revisions. The Seller shall be responsible of submitting the official reports and certifications from Siemens – PTI, otherwise the mathematical model shall not be considered valid.

The Seller shall be responsible to submit Siemens – PTI certified PSSE mathematical models of any kind of compensation devices (ie. SVC, STATCOMs, BESS, etc.) used on the PV facility. It is preferred that the models are standard models provided with PSS/E. In the case that the Seller submits user written models, the PV facility Seller shall be required to keep these models current with the future versions of the PSS/E program until such time that PSS/E has implemented a standard model. In its final form, the mathematical model shall be able to simulate each of the required control and operational modes available for the compensation device and shall be compatible with the latest and future versions of PSSE. The model shall reflect final adjustments and parameters settings related with the control system commissioning process and shall be incorporated to the PSSE mathematical model and tested accordingly by the PV facility Seller and PREPA system study groups. The Seller shall be responsible of submitting the official reports and certifications from Siemens – PTI, otherwise the mathematical models shall not be considered valid.

PV facility Owners that provide user written model(s) shall provide compiled code of the model and are responsible to maintain the user written model compatible with current and new releases of PSS/E until such time a standard model is provided. PREPA must be permitted by the PV facility Owner to make available PV Facility models if required to external consultants with an NDA in place.

The Seller shall submit a PSS/e model validation report. This report shall demonstrate PSS/e simulation results that show the model MTR compliance and performance, based on final adjustment and parameter settings of MTR and commissioning field tests. The Seller shall be responsible of submitting the official reports and certifications from Siemens – PTI, otherwise the mathematical models shall not be considered valid.

Additional details for the adequate PSS/e modeling and the contents of the PSS/e validation report can be found in PREPA's "Guidelines on PSS/e Mathematical Models" document.

14. Transient Mathematical Model

The Seller shall be responsible of providing a detailed transient model of the PV facility and to show that it is capable of complying with PREPA's transient Minimum Technical Requirements.

15. Dynamic System Monitoring Equipment

The Seller of the PV facility shall be required to provide, install and commission a dynamic system monitoring equipment that conforms to PREPA's specifications.

MINIMUM TECHNICAL REQUIREMENTS FOR INTERCONNECTION OF WIND TURBINE GENERATION (WTG) PROJECTS

The Seller shall comply with the following minimum technical requirements:

1. Voltage Ride-Through:

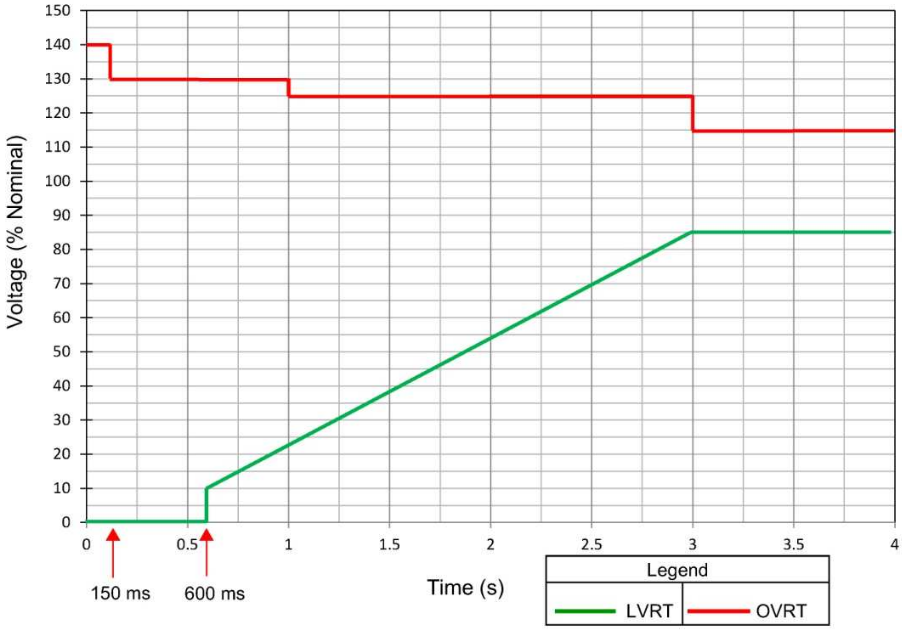

Figure 1 Voltage Ride-Through Requirements

a. PREPA's Low Voltage Ride-Through (LVRT) Requirements:

   i. From Figure 1, PREPA requires all generation to remain online and be able to ride-through three phase and single phase faults down to 0.0 per-unit (measured at the point of interconnection), for up to 600 ms.

   ii. All generation remains online and operating during and after normally cleared faults on the point of interconnection.

iii. All generation remains online and operating during backup-cleared faults on the point of interconnection.

iv. During the low voltage fault conditions, the wind generation facility shall operate on reactive current injection mode. This mode of operation shall be implemented with a reactive current droop characteristic which shall have an adjustable slope from 1 to 5%. A dead band of 15 % is required.

b. PREPA's Overvoltage Ride-Through (OVRT) Requirements:

i. PREPA requires all generation to remain online and able to ride-through symmetrical and asymmetrical overvoltage conditions specified by the following values illustrated in Figure 1:

Overvoltage (pu)	Minimum time to remain online
1.4 – 1.3	150 ms
1.3 – 1.25	1 s
1.25 – 1.15	3 s
1.15 or lower	indefinitely

2. VOLTAGE REGULATION SYSTEM (VRS)

Constant voltage control shall be required. Wind Turbine Generation (WTG) technologies in combination with Static Var Controls, such as Static Var Compensators (SVCs) and STATCOMs are acceptable options to comply with this requirement. A complete and detailed description of the VRS control strategy shall be submitted for evaluation.

a) Wind Generation Facilities (WGF) must have a continuously-variable, continuously-acting, closed loop control VRS; i.e. an equivalent to the Automatic Voltage Regulator in conventional machines.

b) The VRS set-point shall be adjustable between 95% to 105% of rated voltage at the Interconnection Facility (connection to PREPA TC or sectionalizer). The VRS set-point must also be adjustable by PREPA's Energy Control Center via SCADA.

c) The voltage regulation at the Interconnection Facility (connection to PREPA TC or sectionalizer) shall be based in direct measurement of the Interconnection Facility Interconnection Facility (connection to PREPA TC or sectionalizer) voltage. Line drop compensation or similar strategies shall not be permitted.

d) The VRS shall operate only in a voltage set point control mode. Controllers such as Power Factor or constant VAR are not permitted.

e) The VRS controller regulation strategy shall be based on proportional plus integral (PI) control actions with parallel reactive droop compensation. The VRS Droop shall be adjustable from 0 to 10%.

f) At zero percent (0%) droop, the VRS shall achieve a steady-state voltage regulation accuracy of +/- 0.5% of the controlled voltage at the Interconnection Facility (connection to PREPA TC or sectionalizer).

g) The VRS shall be calibrated such that a change in reactive power will achieve 95% of its final value no later than 1 second following a step change in voltage. The change in reactive power should not cause excessive voltage excursions or overshoot. If a voltage overshoot is generated during a change in reactive power its value shall be less than 1%.

h) The generator facility VRS must be in service at any time the WGF is electrically connected to the grid regardless of MW output from the WGF.

i) The VRS dead band shall not exceed 0.1%.

3. Reactive Power Capability and Minimum Power Factor Requirements

The total power factor range shall be from 0.85 lagging to 0.85 leading at the Interconnection Facility (connection to PREPA TC or sectionalizer). The reactive power requirements are necessary to provide support to the system operation based on the voltage profile and reactive power needs. The intent is that a WGF can ramp the reactive power from 0.85 lagging to 0.85 leading in a smooth continuous fashion at the Interconnection Facility (connection to PREPA TC or sectionalizer).

The +/- 0.85 power factor range should be dynamic and continuous at the point of interconnection Interconnection Facility (connection to PREPA TC or sectionalizer). This means that the WGF has to be able to respond to power system voltage fluctuations by continuously varying the reactive output of the plant within the specified limits. The previously established power factor dynamic range could be expanded if studies indicate that additional continuous, dynamic compensation is required. It is required that the WGF reactive capability meets +/- 0.85 Power Factor (PF) range based on the WGF Aggregated MW Output, which is the maximum MVAr capability corresponding to maximum MW Output. It is understood that positive (+) PF is where the WGF is producing MVAr and negative (-) PF is where the WGF is absorbing MVAr.

This requirement of MVAr capability at maximum output shall be sustained throughout the complete range of operation of the WGF as established by Figure 2. The MVAr capability shall also be sustained throughout the complete Interconnection Facility (connection to PREPA TC or sectionalizer) voltage regulation range (95% to 105% of rated voltage at the Interconnection Facility).

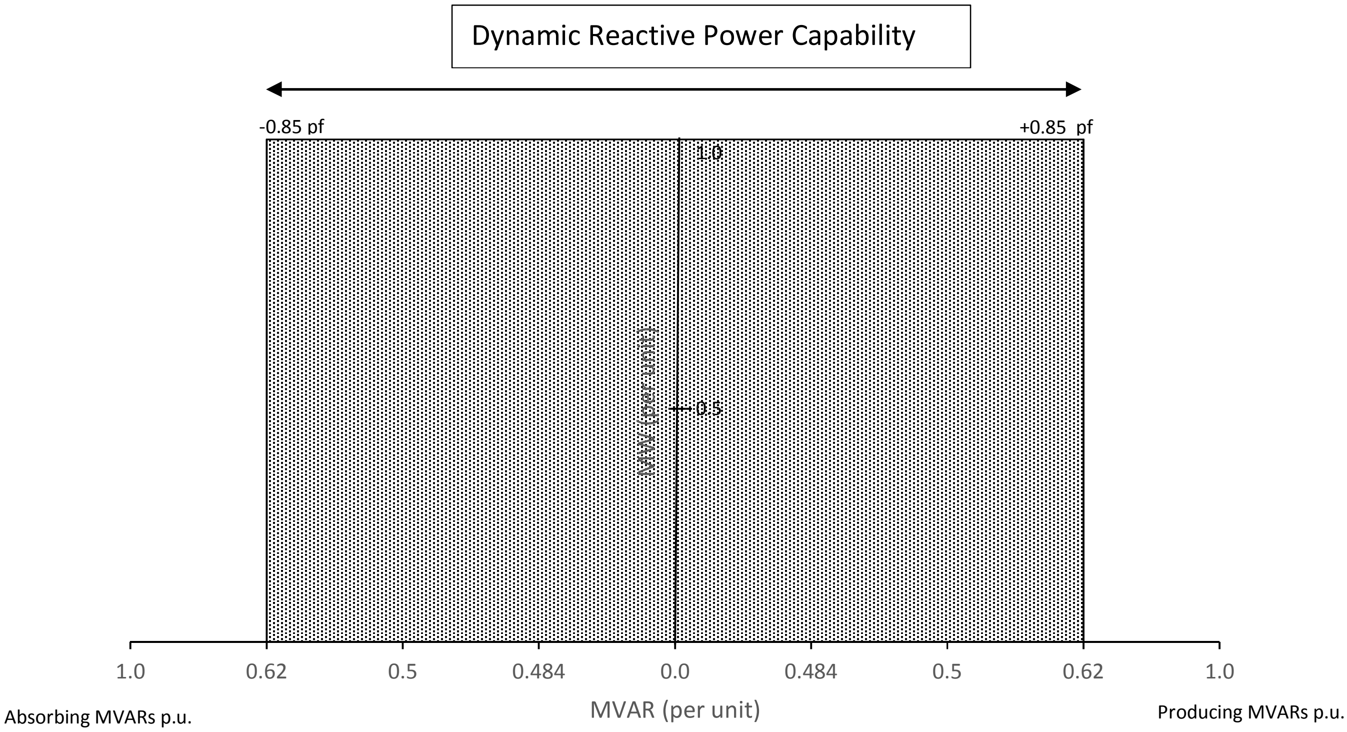

Figure 2 Reactive Power Capability Curve

4. SHORT CIRCUIT RATIO (SCR) REQUIREMENTS:

Short Circuit Ratio values (System Short Circuit MVA at POI/WGF MVA Capacity) under 5 shall not be permitted. The Seller shall be responsible for the installation of additional equipment, such as synchronous condensers, and controls necessary to comply with PREPA's minimum short circuit requirements.

5. FREQUENCY RIDE THROUGH (FRT):

- 57.5 - 61.5 Hz No tripping (continuous)
- 61.5 - 62.5 Hz 30 sec
- 56.5 - 57.5 Hz 10 sec
- < 56.5 or > 62.5 Hz Instantaneous trip

6. Frequency Response/Regulation:

WTG facility shall provide an immediate real power primary frequency response, proportional to frequency deviations from scheduled frequency, similar to governor response. The rate of real power response to frequency deviations shall be similar to or more responsive than the droop characteristic of 3-5% range used by conventional generators. WTG facility shall have controls that provide both for down-regulation and up-regulation. Wind turbine technologies, in combination with energy storage systems such as, but not limited to battery energy storage systems (BESS), and flywheels are acceptable options to comply with PREPA's frequency response and regulation requirements.

The WTG facility response shall be proportional to the frequency deviation, based on the specified 3-5% range droop characteristic. The droop shall be configurable from 3% to 5% in steps of 0.5% (3.0%, 3.5%, 4.0%, 4.5%, 5.0%). The frequency response dead band shall not exceed 0.02%. For large frequency deviations (for example in excess of 0.3 Hz), the WGF shall provide an immediate real power primary frequency response of at least 10% of the maximum AC active power capacity (established in the contract). The time response (full 10% frequency response) shall be less than 1 second. Frequency response shall not be limited by, and shall be decoupled from, the ramp rate control. The frequency response of the facility shall be continuously in operation, even during ramp rate events. After the two decoupled functions are added together, the facility shall be able to simultaneously comply with both requirements.

If energy storage systems are utilized to comply with the frequency regulation requirements, and during a disturbance the system frequency stays below 59.7 Hz, the facility frequency response shall be maintained for at least 9 minutes. After the ninth minute the real power primary frequency response shall not decrease at a ramp rate higher than 10% of the maximum AC active power capacity per minute. The energy storage systems utilized to comply with the frequency regulation requirement shall be designed based on a storage capacity equivalent to at least 9.5 minutes of the 10 % AC contracted capacity measured at the Interconnection Facility (connection to PREPA TC or sectionalizer) for downward frequency events, and a similar amount for upward frequency events. This represents an equivalent of 9 minutes full participation, plus one minute ramp down complying with the ramp rate requirement. This energy will be used on a continuous basis for regulation against frequency deviations. During periods of time were the energy storage system utilized to comply with the frequency regulation requirement is completely charged (cannot absorb more power), the WTGs inverters will assume the responsibility of the upward frequency events. If the energy available for frequency regulation is drained, the function shall be restored in a time period less than 10 minutes and with at least 95% of the energy capacity restored. The energy charging process shall not affect the ramp rate control requirement or the frequency regulation of the grid.

The operational range of the frequency response and regulation system shall be from 10% to 110% of the maximum AC active power capacity (established in the contract). The WGF power output at the POI shall not exceed the maximum AC active power (established in the contract) except to comply with the frequency response requirement.

7. RAMP RATE CONTROL:

Ramp Rate Control is required to smoothly transition from one output level to another. The WTG facility shall be able to control the rate of change of power output during some circumstances, including but not limited to: (1) rate of increase of power, (2) rate of decrease of power, (3) rate of increase of power when a curtailment of power output is released; and (4) rate of decrease in power when curtailment limit is engaged. A 10 % per minute (0.1667 % per second) rate (based on AC contracted capacity) limitation shall be enforced. This ramp rate limit applies both to the increase and decrease of power output and is independent of meteorological conditions. The ramp rate control tolerance shall be +10%.

The energy storage system utilized to comply with the ramp rate control requirement shall be designed based on a minimum storage capacity equivalent to 25 minutes of the 30 % AC contracted capacity measured at the Interconnection Facility (connection to PREPA TC or sectionalizer). The minimum nominal power output capacity of the energy storage system utilized to comply with the ramp rate control requirement shall be 30% of AC contracted capacity measured at Interconnection Facility (connection to PREPA TC or sectionalizer); and for at least one (1) minute, a minimum effective power output capacity of 45% of AC contracted capacity measured at the Interconnection Facility (connection to PREPA TC or sectionalizer). The transition from effective power output capacity to nominal power output capacity shall not exceed the ramp rate requirement of 10% per minute.

The Frequency Response/Regulation and Ramp Rate Control functions shall be decoupled, continuously in operation and the facility shall be able to comply simultaneously with both requirements, while the wind generation facility is generating and injecting power to the grid. This means that the energy storage system shall include, as a minimum: 10% of the contracted capacity for Frequency Response/Regulation for at least 9.5 minutes (see section 6 for details) and 30% of contracted capacity for Ramp Rate Control for at least 25 minutes. The energy storage system shall also be able to provide a minimum effective capacity of 45% of the contracted capacity for at least one (1) minute at the Interconnection Facility (connection to PREPA TC or sectionalizer). Therefore, the minimum acceptable capacity for the energy storage system is a total combined size of 40% of contracted capacity, and for at least one (1) minute, the system has to have an effective capacity of 45% of the contracted capacity.

Rates of change in active power at the wind generation facility's Interconnection Facility (connection to PREPA TC or sectionalizer) in excess of the 10 % per minute rate requirement caused by the loss of generating resource (wind availability) that require more than the minimum storage capacity defined in this MTRs document, will not be considered in non-compliance with the ramp rate control requirement. Therefore, if the ramp is controlled within the limits specified in the requirement, or if the storage system cannot control the ramp rate because it is outside of its minimum required capabilities, but performs as specified, the wind generation facility will not be considered in non-compliance. However, if the energy storage system cannot control the ramp rate as required because does not perform according to at least with the minimum required capabilities specified in this MTRs document, the wind generation facility will be considered in non-compliance.

8. AUTO-CURTAILMENT

The Seller shall implement an auto-curtailment strategy for the WTG Facility to address and compensate deficiencies that can affect the Plant compliance with the MTRs. Some of the conditions to apply auto-curtailment are:

a. A reduction on the reactive power capacity of the facility (by example due to WTGs out of service, any other condition that can reduce the required reactive power capacity of the facility).

b. A reduction in the active power capacity of the storage system (by example loss of some of the battery strings, a BESS inverter out of service, any other condition that can reduce the required active power capacity of the energy storage system).

c. Loss of the Interconnection Facility (connection to PREPA TC or sectionalizer) readings used for the different controls (voltage, frequency, ramp, etc.) of the facility. This can happen due to a malfunction of the equipment used for the Interconnection Facility (connection to PREPA TC or sectionalizer) readings. In this case the curtailment should be to zero.

d. A fault in the Voltage Control, Frequency Response Control, Ramp Rate Control. In this case the facility should be curtailed to zero output.

e. Any other condition not mentioned here but that based in the facility design can cause a non-compliance with the MTRs.

A complete and detailed description of the auto-curtailment strategy shall be submitted for evaluation.

9. Power Quality Requirements:

The Seller shall address, in the design of their facilities potential sources and mitigation of power quality degradation prior to interconnection. Design considerations should include applicable standards including, but not limited to IEEE Standards 142, 519, 1100, 1159, and ANSI C84.1, IEC 61400-21, IEC 61000-3-7 and IEC 61000-3-6. Typical forms of power quality degradation include, but are not limited to voltage regulation, voltage unbalance, harmonic distortion, flicker, voltage sags/interruptions and transients.

10. Wind Power Management

WTG facility shall provide adequate technology (communicating technology and the corresponding control equipment) and implement wind power management requirements (ramp rate limits, output limits, curtailment) as established by PREPA.

11. Special Protection Schemes:

WTG facility shall provide adequate technology and implement special protection schemes as established by PREPA in coordination with wind power management requirements.

12. Wind Generation Forecasting Systems

WTG facility shall provide adequate technology to support wind generation forecasting systems (short term and day-ahead) as established by PREPA. Individual turbine's availability shall be included.

13. General Interconnection Substation Configuration:

An interconnecting generation producer must interconnect at an existing PREPA switchyard, unless otherwise approved by PREPA in the contract. The configuration requirements of the interconnection depend on where the physical interconnection is to occur and the performance of the system with the proposed interconnection. The interconnection must conform, at a minimum, to the original designed configuration of the switchyard. PREPA, at its sole discretion, may consider different configurations due to physical limitations at the site.

14. Modeling and Validation

Once final adjustments and parameter settings related with commissioning and MTR compliance tests are completed, the Seller shall submit a PSS/e Siemens – PTI Certified mathematical model in the version required by PREPA, and validation report.

When referred to the mathematical model, this shall include but is not limited to wind generator, transformers, collector systems, plant controllers, control systems and any other equipment necessary to properly model the WTG facility for both steady-state and dynamic simulation modules.

The Seller shall be required to submit user manuals for both the Wind Turbine Generator and WTG Facility models including a complete and detailed description of the voltage regulation system (VRS) and frequency regulation system model implementation. The mathematical models shall be fully compatible with the latest and future versions of PSS/E. It is preferred that the models are PSS/E standard models. In the case that the Seller submits user written models, the Seller shall be required to keep these models current with the future versions of the PSS/E program until such time that PSS/E has implemented a standard model. The Seller shall submit to PREPA an official report from Siemens - PTI that validates and certifies the required mathematical models, including subsequent revisions. The Seller shall be responsible of submitting the official reports and certifications from Siemens – PTI, otherwise the mathematical model shall not be considered valid.

The Seller shall be responsible to submit Siemens – PTI certified PSSE mathematical models of any kind of compensation devices (ie. SVC, STATCOMs, BESS, etc.) used on the WTG facility. It is preferred that the models are standard models provided with PSS/E. In the case that the Seller submits user written models, the WTG facility Seller shall be required to keep these models current with the future versions of the PSS/E program until such time that PSS/E has implemented a standard model. In its final form, the mathematical model shall be able to simulate each of the required control and operational modes available for the compensation device and shall be compatible with the latest and future versions of PSSE. The model shall reflect final adjustments and parameters settings related with the control system commissioning process and shall be incorporated to the PSSE mathematical model and tested accordingly by the WTG facility Seller and PREPA system study groups. The Seller shall be responsible of submitting the official reports and certifications from Siemens – PTI, otherwise the mathematical models shall not be considered valid.

WTG facility Owners that provide user written model(s) shall provide compiled code of the model and are responsible to maintain the user written model compatible with current and new releases of PSS/E until such time a standard model is provided. PREPA must be permitted by the

Owner to make available WGF models if required to external consultants with an NDA in place.

The Seller shall submit a PSS/e model validation report. This report shall demonstrate PSS/e simulation results that show the model MTR compliance and performance, based on final adjustment and parameter settings of MTR and commissioning field tests. The Seller shall be responsible of submitting the official reports and certifications from Siemens – PTI, otherwise the mathematical models shall not be considered valid.

Additional details for the adequate PSS/e modeling and the contents of the PSS/e validation report can be found in PREPA's "Guidelines on PSS/e Mathematical Models" document.

15. Transient Mathematical Model

The Seller shall be responsible of providing a detailed transient model of the WTG facility and to show that it is capable of complying with PREPA's transient Minimum Technical Requirements.

16. Dynamic System Monitoring Equipment

The Seller of the Renewable Energy Facility shall be required to provide, install and commission a dynamic system monitoring equipment that conforms to PREPA's specifications.

MINIMUM TECHNICAL REQUIREMENTS FOR BATTERY ENERGY STORAGE SYSTEM (BESS) FACILITIES

The Seller for BEES facilities shall comply with the following minimum technical requirements:

a) Frequency Control and Regulation

1. Fast active power (P) source capable of continuously injecting or absorbing energy from the grid as a function of system frequency deviations to help manage and maintain frequency at 60 Hz.

2. Instantaneous and immediate active power (P) response of BESS proportional to frequency deviations from scheduled frequency.

3. Rate of active power (P) response of BESS to frequency deviations shall be established based on configurable Authority selected droop characteristic (for example 5% droop characteristic or more responsive as selected by the Authority via SCADA). The droop shall be programmable and configurable by the Authority via SCADA from 1% to 5% in steps of 0.5% (for example: 1.0%, 1.5%, 2.0%, 2.5%...4.5%, 5.0%).

4. A frequency regulation deadband shall be available. The deadband shall be configurable and programmable by the Authority via SCADA. The configurable deadband range shall be at least from 0.02% to 0.5%.

5. The BESS frequency control and regulation mode time response (full frequency response) shall be less than 1.0 second.

6. Frequency regulation range (upper injection/lower absorption limits) should be configurable and selected by the Authority via SCADA up to a maximum of its nominal capacity (for example +/- 15 MW, +/- 20 MW, etc.). Asymmetrical frequency regulation ranges should be allowed (as for example +15 MW/-5 MW, +10 MW/-20 MW, etc.)

7. Capability to operate in the frequency control and regulation mode and simultaneously control the voltage by the injection or absorption of up to the required nominal reactive power at the point of interconnection. The frequency regulation control shall operate decoupled from the voltage regulation control mode and shall not limit the required reactive power capability of the Facility at the point of interconnection. Neither shall the voltage regulation control limit the required active power capability of the Facility at the Point if Interconnection.

b) Rapid Spinning Reserve and Fast Frequency Response

1. Instantaneous injection of reserve energy as a function of the rate of change and/or deviations of the system frequency in the event of a sudden loss of generation or unexpected ramp-up in demand.

2. Energy capability and power capacity to inject nominal active power output (at the Point of Interconnection) in a range from 2 to 6 hours of discharge.

3. Injection of active power (P) within the first 3 cycles of a specific frequency deviation trigger and/or a frequency rate of change trigger (triggers shall be configurable and selected by the Authority).

    a. Total configurability for the Authority selection of the active power output, response time and response slope.

    b. Total configurability for the Authority selection of triggers: frequency, rate of change of frequency and instantaneous/time delay combinations.

    c. As for example, the rapid reserve might be selected to trigger if frequency decays to 59.6 Hz at a rate > 0.25 Hz/sec or drops and stays between 59.0 Hz and 59.2 Hz for > 30 seconds or drops below 59 Hz.

    d. Total configurability for multiple sets of triggering combinations capable of being simultaneously active. The rapid reserve mode might be selected to trigger with Boolean or logical operators that combine active power output, response time, response slope, frequency limits, frequency rate of change and time delay.

4. The rapid spinning reserve mode shall provide a full output response time (95% of its final output value) of 100 milliseconds or faster. The Authority shall also have the flexibility of selecting a limited rapid spinning reserve sub-mode from SCADA. In limited rapid spinning reserve sub-mode, the active power output, response time and response slope shall be configurable and programmable from SCADA in accordance with the triggering combinations and options previously discussed.

5. Capability to inject 150% of nominal active power output for 60 seconds at required 100 milliseconds response time. The BESS shall provide the Authority with the flexibility to enable and disable this capability from SCADA. If selected from SCADA, this option shall be simultaneously active with previously selected multiple sets of triggering combinations.

6. Capability to inject 120% of nominal active power output for 90 seconds at required 100 msec. response time. The BESS shall provide the Authority with the flexibility to enable and disable this capability from SCADA. If selected from SCADA, this option shall be simultaneously active with previously selected multiple sets of triggering combinations.

7. Capability to ramp down active power output at PREPA's pre-selected and configurable slope (MW/min or % of active power output/min) after system frequency is normalized and triggers pre-selected and configurable frequency window for a certain amount of time. It shall ramp down to PREPA's pre-selected and configurable active power output (10 MW, 5 MW, 0 MW, etc.) and be able to automatically make the transition and continue operating in frequency control and regulation mode in accordance with previously selected and configurable parameters. The active power automatic ramp down should have the capability of being manually interrupted from SCADA if necessary. Capability to be manually ramped down from SCADA if selected by the Authority shall also be

available.

a. Total configurability of ramp down slope in MW/minute or % of active power output/minute.

b. Total configurability of active power output target to which the BESS shall ramp down before making the transition to operate in frequency control and regulation mode.

c. Total configurability for the Authority selection of frequency triggers that initiate rapid reserve ramp down process: frequency limits of window range and time delay combinations that initiate ramp down.

d. As for example, rapid reserve ramp down might be triggered if frequency returns to 60 Hz +/- 0.1 Hz and stays in this range for at least 20 seconds or returns to 60 Hz +/- 0.2 Hz and stays in this range for at least 30 seconds.

8. Capability to ramp down active power output at PREPA's pre-selected and configurable slope (MW/min or % of active power output/min) after SCADA command is received from PREPA's Energy Control Center System Operator to automatically make the transition and continue operating in frequency control and regulation mode in accordance with previously selected and configurable parameters.

    a. Total configurability of ramp down slope in MW/minute or % of active power output/minute

    b. Total configurability of active power output target to which the BESS shall ramp down before making the transition to operate in frequency control and regulation mode

9. Capability to inject nominal active power output for 1.0 hour and simultaneously inject or absorb nominal reactive power at the point of interconnection.

c) Dispatchable Generation Source

1. Injection of active power at point of interconnection for a limited period of time to cover temporary generation deficits or start-up fast generating units.
2. Constant power output mode, active power (P) magnitude and time period to be selected by PREPA from SCADA.
3. Capability to automatically make the transition from dispatchable mode to frequency control and regulation mode in accordance with previously selected and configurable parameters after SCADA command is received from PREPA's Energy Control Center System Operator.
4. Capability to ramp down active power output at PREPA's pre-selected and configurable slope (MW/min or % of active power output/min) after SCADA command is received from PREPA's Energy Control Center System Operator to automatically make the transition from dispatchable mode to frequency control and regulation mode in accordance with previously selected and configurable parameters.

    a. Total configurability of ramp down slope in MW/minute or % of active power output/minute

    b. Total configurability of active power output target to which the BESS shall ramp down before making the transition to operate in frequency control and regulation mode

5. Capability to operate in the dispatchable generation source mode and simultaneously control the voltage by the injection or absorption of up to nominal reactive power at the point of interconnection.

d) Voltage Regulation and Control

1. Dynamic reactive power compensation source capable of continuously injecting or absorbing reactive power (up to +/- nominal MVAR at point of interconnection) as a function of system voltage deviations.

2. Voltage regulation strategy based 100 % on power electronics technology

(no passive components like capacitors or reactors, neither thyristor controlled or switched capacitors or reactors allowed to complement reactive power capability).

3. Constant voltage control shall be required (voltage set point control mode).

4. The voltage regulation set points shall be adjusted by PREPA from SCADA between 95% and 105% rated voltage at the Interconnection Point. Because the previous voltage regulation range could be expanded (for example up to 106%) if PREPA's internal analyses indicate that additional dynamic compensation is required for specific multi-contingency scenarios, the upper voltage set point limits should be totally configurable and adjusted from SCADA beyond the typical voltage regulation range if necessary.

5. The voltage regulation shall be based on direct measurement by means of new BESS dedicated potential transformers (to be installed by Contractor) at the point of interconnection.

6. The voltage regulation system strategy shall be based on proportional plus integral (PI) control actions with parallel reactive droop compensation. The voltage regulation droop shall be adjustable from 0 to 10% in steps not greater than 0.5%.

7. At zero percent (0%) droop, the voltage regulation system shall achieve a steady-state voltage accuracy of +/- 0.3% of the controlled voltage at the point of interconnection. For voltage regulation droops between 0 and 2.5%, the voltage regulation system shall be calibrated such that a change in reactive power will achieve 95% of its final value no later than 1 sec following a step change in voltage. The change in reactive power should not cause excessive voltage excursions or overshoot. If a voltage overshoot is generated, it should be less than 1%.

8. For voltage regulation droops between 2.5% and 5.0%, the voltage regulation system shall be calibrated such that a change in reactive power will achieve 95% of its final value no later than 500 msec following a step

change in voltage. The change in reactive power should not cause excessive voltage excursions or overshoot. If a voltage overshoot is generated, it should be less than 1%.

9. For voltage regulation droops between 5% and 10%, the voltage regulation system shall be calibrated such that a change in reactive power will achieve 95% of its final value no later than 100 msec following a step change in voltage. The change in reactive power should not cause excessive voltage excursions or overshoot. If a voltage overshoot is generated, it should be less than 1%.

10. The voltage regulation system dead band shall not exceed 0.1%.

11. The voltage regulation system shall be programmed to control and coordinate with local power transformers tap changers and local reactive power sources physically located in the switchyard.

e) Fast Dynamic Reactive Power Reserve and Voltage Support

1. Instantaneous or slope controlled (MVAR/sec) injection or absorption of reactive power triggered by and as a function of the rate of change and/or deviations of the system voltage.

2. Injection of reactive power (Q) within the first 3 cycles of a specific voltage deviation trigger and/or a voltage rate of change trigger (triggers are configurable and selected by PREPA).

    a. The maximum final reactive power output value for fast dynamic reactive power reserve shall be configurable and selected from SCADA by PREPA, up to the nominal reactive power capacity.

    b. Total configurability for PREPA selection of triggers: voltage magnitude, rate of change of voltage and instantaneous/time delay combinations.

    c. As for example, fast dynamic reactive power reserve might be selected to trigger if voltage decays to 0.95pu kV at a rate > 2.0 kV/sec or drops below 0.9pu.

d. As for example, a different value of fast dynamic reactive power reserve might be selected to trigger if voltage decays to 0.95pu at a rate > 1.0 kV/sec or drops below 0.93pu.

3. A full output response time (95% of its final output value) of 100 msecs. or faster is required. The maximum overshoot should not exceed 5% of the ordered change and the settling time should not exceed 150 msec.

4. Capability to inject 120% of nominal reactive power output for 3 seconds at required 100 msec. response time.

5. Absorption of reactive power (Q) within the first 3 cycles of a specific voltage deviation trigger and/or a voltage rate of change trigger (triggers are configurable and selected by PREPA).

    a. The minimum final reactive power output value for fast dynamic reactive power absorption shall be configurable and selected from SCADA by PREPA, up to the nominal reactive power capacity of the BESS.

    b. Total configurability for PREPA selection of triggers: voltage magnitude, rate of change of voltage and instantaneous/time delay combinations.

    c. As for example, fast dynamic reactive power might be selected to trigger if voltage increases to 1.1pu of the nominal voltage at a rate > 3.0 kV/sec or increases above 1.2pu of the nominal voltage.

    d. A different fast dynamic reactive power might be selected to trigger if voltage increases to 1.1pu of nominal voltage at a rate > 2.0 kV/sec or increases above 1.15pu of nominal voltage.

6. Capability to inject nominal fast dynamic reactive power reserve or operate in voltage regulation mode depending on the system voltage

conditions, and simultaneously inject nominal active power output for 1.0 hour at the point of interconnection.

f) Black Start Capability

1. The Facility shall provide for the BESS start-up capability and full functionality during system blackouts.

2. The Facility shall provide for the BESS start-up capability and full functionality during unavailability of external system generation sources.

g) BESS Full Functional Voltage and Frequency Operational Range and Ride-Through Capability

1. Low Voltage Operational Range

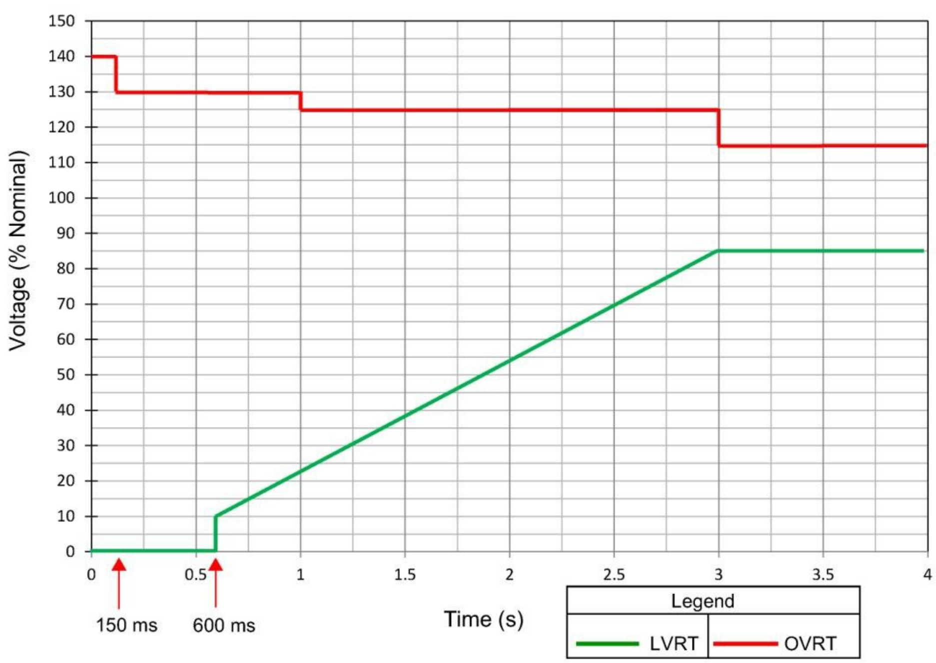

Figure 1 BESS Voltage Operational Range and Ride-Through Requirements

a. From Figure 1, the Authority requires the BESS to remain totally functional and online during three phase and single phase faults down to 0.0 per-unit (measured at the point of interconnection), for up to

600 msec.

b. The BESS shall remain online and continue operating during and after normally cleared faults on the point of interconnection.

c. The BESS shall remain online and continue operating during and after backup-cleared faults.

2. High Voltage Operational Range

The Authority requires the BESS to remain totally functional and online during symmetrical and asymmetrical overvoltage conditions as specified by the following values illustrated in Figure 1:

Overvoltage (pu)	Minimum time
1.4 – 1.3	150 ms
1.3 – 1.25	1 s
1.25 – 1.15	3 s
1.15 or lower	indefinitely

3. Frequency Ride Through (FRT):

- 56.0 – 63.0 Hz No tripping (continuous operation)
- 55.5 – 56.0 Hz 20 sec time delay
- < 55.5 or > 63.0 Hz Instantaneous trip

h) Dynamic System Monitoring Equipment (DSM)

The Seller shall be required to provide, install , commission and maintain a dynamic system monitoring equipment that conforms to PREPA's specifications and signals list.

i) Modeling and Validation

Once final adjustments and parameter settings related with commissioning and MTR compliance tests are completed, the Contractor shall submit a PSS/e Siemens – PTI Certified mathematical model and validation report.

When referred to the mathematical model, this shall include but is not limited to inverters, transformers, collector systems, plant controllers, control systems and any other equipment necessary to properly model the BESS facility for both steady-state and dynamic simulation modules.

The Contractor shall be required to submit user manuals for both the BESS unit and BESS Facility models including a complete and detailed description of the voltage regulation system (VRS) and frequency regulation system model implementation. The mathematical models shall be fully compatible with the latest and future versions of PSS/E. It is preferred that the models are PSS/E standard models. In the case that the Contractor submits user written models, the Contractor shall be required to keep these models current with the future versions of the PSS/E program until such time that PSS/E has implemented a standard model. The Contractor shall submit to PREPA an official report from Siemens - PTI that validates and certifies the required mathematical models, including subsequent revisions. The Contractor shall be responsible of submitting the official reports and certifications from Siemens – PTI, otherwise the mathematical model shall not be considered valid.

The Contractor shall be responsible to submit Siemens – PTI certified PSSE mathematical models of any kind of compensation devices (i.e. SVC, STATCOMs, BESS, etc.) used on the BESS facility. It is preferred that the models are standard models provided with PSS/E. In the case that the Contractor submits user written models, the BESS facility Contractor shall be required to keep these models current with the future versions of the PSS/E program until such time that PSS/E has implemented a standard model. In its final form, the mathematical model shall be able to simulate each of the required control and operational modes available for the compensation device and shall be compatible with the latest and future versions of PSSE. The model shall reflect final adjustments and parameters settings related with the control system commissioning process and shall be incorporated to the PSSE mathematical model and tested accordingly by the BESS facility Contractor and PREPA system study groups. The Contractor shall be responsible of submitting the official reports and certifications from Siemens – PTI, otherwise the mathematical models shall not be considered valid.

BESS facility Owners that provide user written model(s) shall provide compiled code of the model and are responsible to maintain the user written model compatible with current and new releases of PSS/E until such time a standard model is provided. PREPA must be permitted by the Owner to make available WGF models if required to external consultants with an NDA in place.

The developer shall submit a PSS/e model validation report. This report shall demonstrate PSS/e simulation results that show the model MTR compliance and performance, based on final adjustment and parameter settings of MTR and commissioning field tests. The Contractor shall be responsible of submitting the official reports and certifications from Siemens – PTI, otherwise the mathematical models shall not be considered valid.

Additional details for the adequate PSS/e modeling and the contents of the PSS/e validation report can be found in PREPA's "Guidelines on PSS/e Mathematical Models" document.

j) Power Quality Requirements

The Seller shall address, in the design of their facilities potential sources and mitigation of power quality degradation prior to interconnection. Design considerations should include applicable standards including, but not limited to IEEE Standards 142, 519, 1100, 1159, and ANSI C84.1. Typical forms of power quality degradation include, but are not limited to voltage regulation, voltage unbalance, harmonic distortion, flicker, voltage sags/interruptions and transients.

k) Power Management

BESS facility shall provide adequate technology (communicating technology and the corresponding control equipment) and implement power management requirements (ramp rate limits, output limits, curtailment) as established by PREPA.

l) Short Circuit Ratio (SCR) Requirements

Short Circuit Ratio values (System Short Circuit MVA at POI/BESS Facility MVA Capacity) under 5 shall not be permitted. The Seller shall be responsible for the installation of additional equipment, such as synchronous condensers, and controls necessary to comply with PREPA's minimum short circuit requirements.

m) General

1. For batteries, replacement of individual cells or cell modules shall not interrupt BESS availability to the grid.

2. The BESS shall have dedicated auxiliary electric power systems to serve BESS ancillary loads (HVAC, lighting, etc.) and be able to be auto-transferred to a reliable backup source.

3. The BESS shall have a minimum round trip energy efficiency of 90%.

4. The BESS point of interconnection voltage level shall be defined with PREPA. The Project proposal shall include appropriate step-up transformers and required interconnection equipment, including any necessary augmentation or modification to existing substation or transmission facilities.

5. The BESS control system shall integrate the following operational requirements:

    a. The BESS controllers shall be compatible with the systems used in PREPA's System Operations Control Center and Energy Management System.

    b. The BESS shall be completely dispatchable.

    c. The BESS control system shall provide available energy forecasting.

    d. Any operating function shall be capable of being remotely and dynamically selected and prioritized.

    e. Function parameters (i.e., droop setting) of any operating function shall be capable of being remotely modified.

    f. The Seller shall fully describe and demonstrate how the proposed BESS control system(s) will operate.

    g. The control system shall have the necessary hardware and software (i.e. firewalls & malware detection) such that it is compliant with the latest NERC CIP reliability standards for control system security requirements.