nationalgridESO

Stability Pathfinder Phase Two:

Technical Performance Requirements

Definitions

Point of Stability:

The point on the transmission system (at 132kV or higher) where the solution is directly or radially connected. This the point where, unless otherwise stated, all service procured in this contract must be delivered.

Part A - Stability Requirements

Short circuit level and inertia requirement

1.1. The **Provider' Plant** shall:

1.1.1. ensure that during a fault, the short circuit level contribution from the Facility will be XX MVA at the point of stability first busbar at High Voltage end of the connection transformer. Short circuit level defined as in Equation 1.:

$$\textbf{Short circuit level (MVA)} = \sqrt{3} * \textbf{Rated voltage (kV)} * \textbf{Fault current(kA)} \quad \text{Equation 1}$$

Where:

the fault current is defined as the instantaneous positive sequence minimum RMS fault current seen at 100ms between 5ms after a 3-phase symmetrical fault at the point of stability and the fault clearance (140 ms);

and Rated voltage is defined as the voltage of first busbar at the point of stability High Voltage end of the connection transformer and is 132kV or above.

~~1.1.2. Provide an inertia response equivalent to a synchronous machine with XX MJ[1] of kinetic energy stored in its rotating shaft at synchronous speed.[2]~~

1.1.2. Provide an inertia response with an inertia of XX MW.s or MJ.

Inertia shall be defined as in Equations 2 and 3:

$$\textbf{Inertia} = \boldsymbol{H} \times \boldsymbol{S_{rating}} \quad \text{Equation 2}$$

$$\boldsymbol{H} = \frac{\Delta P\, f_0}{2\, S_{rating} RoCoF} \quad \text{Equation 3}$$

Where:

H is the inertia constant (s) defined in Equation 3

S_{rating} is the solution rating (MVA)

ΔP is the solution active power output for a frequency event (MW)

f_0 is the pre-fault system frequency (Hz)

~~[1] Where MJ is being considered equivalent to MVA.s or MW.s (at unity power factor)~~
~~[2] Non-synchronous providers should declare an equivalent value taking into account their converter rating and energy store.~~

RoCoF is the rate of change of frequency of the system. (Hz/s)

For a GFC, H must be set such that inertia power is provided without hitting converter's overload or rated capability for a RoCoF of less than 1Hz/s.

Fault ride-through and transient stabilisation requirement

1.2. The **Facility** must be able to:

1.2.1. operate across a range of transmission short circuit levels between [x] and [y][3]

1.2.2. fully comply with the applicable requirements of the Grid Code including but not limited to the Planning Code (PC), Connection Condition (CC's) or European Connection Condition (ECC's), Compliance Processes (CP's) or European Compliance Processes (ECP's), Operating Codes, Balancing Codes and Data Registration Code (DRC)

For the avoidance of doubt where this contract refers to a specific section of Grid Code the facility is expected to comply with the referred section in addition to its normal Grid Code obligations.

1.2.3. during a fault or voltage depression which falls below 0.9 pu at the point of stability ~~Grid Entry Point or User System Entry Point or Transmission Interface Point~~, keep the phase, magnitude and frequency of the Internal Voltage Source fixed at its pre-fault value during and immediately after the fault. In the event that the resulting fault current would have exceeded its maximum overload capability or rated capability, a limited ~~reduced~~ fault current can be supplied up to its maximum overload capability providing this value is reflected in Part A 1.1.1

1.2.4. following an instantaneous vector shift/phase angle change at the point of stability ~~Grid Entry Point, User System Entry Point or Transmission Interface Point~~ provide an instantaneous response (starting within 5ms) in active and/ or reactive current proportional to the angle change up to the values in Part A 1.1.1 and Part A 1.1.2

In the event that the resulting current would exceed its maximum overload capability or rated capability, a limited current can be supplied up to its maximum overload capability providing this value is reflected in Part A 1.1.1 and Part A 1.1.2

~~1.2.4.~~1.2.5. Inherently respond to a change in the system frequency by importing or exporting Inertia Power into the system proportional to the rate of change of frequency of the system

In the event that the resulting Inertia power would have exceeded its maximum overload capability or rated capability, a limited Inertia power can be supplied up to its maximum overload capability providing this value is reflected in Part A 1.1.1

Inertia Power here is defined as the (start of an) instantaneous short-term transfer of active power from the facility to or from the System following a system frequency change as a result of an instantaneous change in generation or demand on the system. This should occur without the need for any change in the Internal Voltage Source of the Facility.

[3] Values will be site specific and to be provided by the ESO at the feasibility stage (expected to within the range of 3-13 kA)

1.2.5.1.2.6. start importing or exporting inertia power to respond to a change in the system frequency within 5ms

1.2.6.1.2.7. provide reactive current and inertia power response to the system consistent with the performance of a voltage source behind an effective impedance. For frequencies below 5Hz additional power transfer can occur due to control based real power requirements. The control system can respond to changes in external signals but with a bandwidth below 5Hz to avoid AC System resonance problems. provide reactive current and inertia power response to the system consistent with the performance of a voltage source behind an effective impedance across all timescales

1.2.7.1.2.8. provide continuous voltage support through the injection of reactive current during a fault condition as defined in ECC.6.3.15. During a fault or voltage disturbance, priority should be given to the injection of reactive current whilst ensuring that active power recovery satisfies the requirements of ECC.6.3.15 (as applicable), though equally the performance expected from a synchronous machine would also be considered appropriate for this requirement

1.2.8.1.2.9. start responding within 5ms of fault clearance during an over-voltage condition at the point of stability Grid Entry Point, User System Entry Point or Transmission Interface Point, as described in paragraph 1.2.187, with reactive current absorption

1.2.10. in the event where the voltage at the Grid Entry Point or User System Entry Point falls below the voltage level specified in ECC.6.1.4, be capable of reactive current injection at the Grid Entry Point or User System Entry Point as soon as possible and starting within at least within 5ms of the voltage disturbance using the whole machine rating and proportional to the size of the voltage dip. in the same way as would be expected from a synchronous machine of an equivalent rating

In the event that the resulting reactive current injection current would have exceeded its maximum overload capability or rated capability, a limited current can be supplied up to its maximum overload capability.

1.2.9.1.2.11. ensure continuous and controllable operation shall be possible at all system voltages specified in ECC6.1.4.1 of the Grid Code

1.2.12. ensure continuous and controllable operation shall be possible at all system frequencies specified in ECC6.1.2.1.2 of the Grid Code

1.2.10.1.2.13. ensure continuous and controllable operation shall be possible at all system rate of change of frequencies up to 1Hz/s

1.2.11.1.2.14. ride through voltage depressions at the Grid Entry Point or User System Entry Point or Transmission Interface Point of down to 0pu for up to 140ms

1.2.12.1.2.15. ride through the family of voltage depressions curves defined in ECC.6.3.15

1.2.13.1.2.16. withstand, and ride through, any rate of change of frequency occurring ≤ 1Hz/s (for GFC ≤ 2 Hz/s) on average or in absolute change across a sampled window of 500ms

1.2.14.1.2.17. withstand, and ride through, any rate of change of frequency instantaneously measured exceeding 1Hz/s within the sampled window period

~~1.2.15.~~1.2.18. withstand an initial RMS over-voltage at the Grid Entry Point or User System Entry Point or Transmission Interface Point, of up to 1.4p.u. for 100ms after fault clearance followed by a reduction in over-voltage towards no more than 1.05pu as per the requirements of TGN(E)288

~~1.2.16.~~1.2.19. confirm the ability of the facility to operate repeatedly through balanced and unbalanced faults and System disturbances each time the voltage at the Grid Entry Point or User System Entry Point or Transmission Interface Point falls outside the limits specified in ECC.6.1.4. Demonstration of this capability would be satisfied by EU Generators and HVDC System Owners and Non-CUSC Parties supplying the protection settings of their Grid Forming Plant, informing The Company of the maximum number of repeated operations that can be performed under such conditions and any limiting factors to repeated operation such as protection or thermal rating

Power Oscillation Damping

1.2.20. The Facility shall be capable of active and/or reactive power oscillation damping achieved over a duration of 20s. The power oscillation damping shall:

1.2.20.1. inherently or through a control system contribute to damping sub-synchronous frequency oscillations in the system's active or reactive power range over a frequency bandwidth of 0.3-2 Hz;

1.2.20.2. inject active or reactive current [4]adequately in antiphase to achieve a reduction in oscillations (as described in 1.2.19.1) at the point of stability;

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1.2.20.3. change the amount of active or reactive current injection proportional to the amplitude of the oscillations;

1.2.20.4. ensure the influence of any subsidiary control functions be no more than 10% of the machine rating.

1.2.21. If the Facility is to operate with a Power System Stabilizers (PSS) capability as specified through its Bilateral Connection Agreement and GB Grid Code then this PSS mode shall be used instead of the Power Oscillation damping specified in 1.2.20. If at any time during the length of the Stability Compensation Service, the Facility is not operating with a PSS then, the facility will need to meet requirements set out in 1.1.20.

~~1.2.17. If the Facility is a synchronous generating unit as defined under the Grid Code, and has a TEC >0MW during the length of the Stability Compensation Service, the Power System Stabilizers (PSS) capability as specified through the Bilateral Connection Agreement and GB Grid Code is needed. If at any time during the length of the Stability Compensation Service, the Facility will reduce its TEC to 0MW, the facility will need to meet clauses set out in 1.2.21~~

~~1.2.18. If the Facility is a power electronics converter based system or comprises of wind farm power park modules with a TEC >0MW during the length of the Stability Compensation Service, the Facility shall be capable of active and/or reactive power oscillation damping achieved over a 20s period. If at any time during the length of the~~

[4] If a solution has a source of active power it is expected to inject active and reactive power as needed. For solutions without a source of active power, a reactive power injection only is required.

Stability Compensation Service, the Facility reduces its TEC to 0MW, the facility will need to meet clauses set out in 1.2.21. The power oscillation damping shall:

1.2.18.1. detect sub-synchronous frequency oscillations in the system's active or reactive power range over a frequency bandwidth of 0.3-2 Hz;

1.2.18.2. upon detecting oscillations, inject active or reactive current adequately in antiphase to achieve a reduction in oscillations at the Grid Entry Point;

1.2.18.3. change the amount of active or reactive current injection proportional to the amplitude of the oscillations;

1.2.18.4. ensure the influence of these subsidiary control functions be no more than 10% of the primary function.

1.2.19. If the Facility is a demand under the Grid Code or has a TEC of 0MW during the length of the Stability Compensation Service, the facility must be capable of reactive power oscillation damping achieved over 20s. The power oscillation damping shall:

1.2.19.1. detect sub-synchronous frequency oscillations in the system's active or reactive power range over a frequency bandwidth of 0.3-2 Hz;

1.2.19.2. upon detecting oscillations, inject reactive current adequately in antiphase to achieve a reduction in oscillations at the Grid Entry Point;

1.2.19.3. change the amount of reactive current injection proportional to the amplitude of the oscillations;

1.2.19.4. ensure the influence of these subsidiary control functions be no more than 10% of the primary function.

Part B - Continuous Voltage Requirements

General requirement

1. The Facility shall, following an Instruction, provide Reactive Power in MVAr of up to [x] pu of MVA rating continuously generating (over-excited) and alternatively of up to [x] pu of MVA rating continuously absorbing (under-excited) of the Facility rating[5].

   The reactive range values must be achievable at the Grid Entry Point or User System Entry Point or Transmission Interface Point as applicable.

2. The Facility's excitation and voltage control shall be,

   2.1. In accordance with paragraph 3 if the facility is connecting as a generator or interconnector under the Grid Code, OR

   2.2. In accordance with paragraphs 4 if the facility is connecting as demand and/or is a 0MW connection under the Grid Code

3. Generation or interconnector connection

   3.1. The Facility's excitation and voltage control shall be in accordance with the relevant section of the Grid Code as specified in the Facility's Bilateral Connection Agreement.

[5] Reactive generation and absorption values to be as specified by the Provider in its tender submission.

4. Demand and/or 0 MW connection

4.1. Control Modes: General

4.1.1. The Facility must be able to operate in either 'Target Voltage' or 'Constant MVAr' mode.

4.1.2. In 'Target Voltage' mode, the unit reactive power injected or absorbed shall be directly proportional to the deviation of the system (HV) voltage from the preselected 'Target Voltage.'. In this mode, the Facility must also provide the stability requirements set out in Part A.

4.1.3. In 'Constant MVAr' mode, the MVAr output of the Facility equals the 'Target MVAr' setting. The Facility must still respond rapidly to sudden changes in system voltage, its output returning steadily to the target value over a definable subsequent period. In this mode, the Facility must also provide the stability requirements set out in Part A.

4.1.4. The Facility must be able to switch between 'Target Voltage 'mode and 'Constant MVAr' mode on instruction from the company within an agreed time scale of no longer than 30 minutes.

4.2. Target Voltage Mode

Slope Characteristic:

4.2.1. A change in voltage (at the point of connection to the NETS) shall cause a change in reactive current according to a linear slope characteristic, defined as the change in system voltage to cause the reactive power output of the Facility to move from zero to full capacitive (over-excited). Control according to the slope characteristic shall be achievable over the full range of reactive outputs and system voltages. Different slopes may be requested in the capacitive and inductive direction.

4.2.2. The slope shall be adjustable over the range 2% to 7%. The setting tolerance shall be better than ±0.5% of system voltage. The Slope shall be adjustable remotely and following an instruction by the Company. The Facility must provide such data as the Company reasonably requires for system modelling studies.

Float Condition:

4.2.3. The float condition, at which reactive power is zero, shall be changed by adjustment of target voltage (at the point of connection to the NETS) over the range 0.95 to 1.05 pu.

4.2.4. The range of slope adjustments is to be available over the full range of target voltage adjustments.

Response Time:

4.2.5. For a sustained change in the NETS voltage, the change in the sustained reactive power will be determined by the slope.

4.2.6. For a step change in the System voltage, the change in sustained reactive current will be achieved as follows;

4.2.6.1. 95% of the total change to be achieved within 1 second; and

4.2.6.2. all oscillations greater than 5% of full load current to have ceased within 5 seconds.

4.3. Constant MVAr Mode

4.3.1. The control system shall adjust the target voltage so that the MVAr output of the Facility equals the 'Constant MVAr' setting. The Facility will thus still respond rapidly to sudden changes in system voltage, its output returning steadily to within (+/ - 2% of unit MVAr rating) of the target value over the subsequent 5 minute period.

4.3.2. Should the voltage on the NETS vary outside adjustable preset limits, the Facility must automatically be switched to Target Voltage Mode to control the abnormal system voltage. This change of operating mode shall be alarmed to alert the Company operator to a possible abnormal system condition. The preset limits shall be adjustable between 0.93 and 1.07 pu, with a resolution of 0.005 pu[6].

4.3.3. The requirements of the 'Constant MVAr' mode must be achievable for all system short circuit levels specified in Part A 1.2.1. Constant MVAr control must be achievable at any MVAr output and at any system voltage within the limits defined in paragraph 1 of Part B and at any system voltage and frequencies as defined in 1.2.11 to 1.2.12 of Part A.

Part C - Control and Indication Facilities

1. Where applicable ~~T~~the transformer tap position shall be provided for by the Provider at the Company's operational metering system control and data acquisition (SCADA) outstation interface, as specified in the Provider's Bilateral Connection Agreement.

2. Where Applicable the following facilities for voltage/reactive power control to the Company's instructions shall be provided by the Provider at a manned control point:

2.1. Start-up of machine and transition to Stability Compensation mode.

2.2. Shut-down of Stability Compensation mode.

2.3. Target voltage setting (resolution 1kV) (for *Target Voltage* control mode).

2.4. Target MVAr setting (resolution 1MVAr) (for *Constant MVAr* control mode).

2.5. Control mode selection (Target Voltage or Constant MVAr).

2.6. Slope setting (range 2% to 7%, resolution 0.5%.)

3. The following additional facilities for voltage/reactive power control shall be provided by the Provider. The Provider shall use all reasonable endeavours to adjust any of the following specified quantities on the Company's instruction within 24 hours' notice. Adjustments including 3.1 and 3.2 shall not be made unless instructed by the Company.

[6] Guidance on the behaviour of the target voltage mode outside of preset limit will be provided by the company upon contract signature.

3.1. Change the time for switching between Target Voltage mode and Constant MVAr mode (The value shall be within the range 5 minutes to 30 minutes, with a resolution of 5 minutes).

3.2. Change the voltage limits for transition to Target Voltage mode (The setting shall be within range 0.93 to 1.07 pu. with a resolution of 0.005 pu).

Part D - Model Provision

The Provider will prior to commissioning the Facility, submit a steady state and transient model in accordance with Grid Code PC.A.5.3.2 c option 2 or PC.A.5.4.2 as appropriate. The Company may accept a DIGSILENT PowerFactory Model V15 provided that this is an open model (i.e. transfer functions visible and not containing DLL code). The provider must submit an EMT PSCAD model if the Company requests before or after commissioning of the Facility.

The Provider will submit a performance chart in accordance with Grid Code OC2.4.2.1