ECC.6.3.7 FREQUENCY RESPONSE

ECC.6.3.7.1 Limited Frequency Sensitive Mode – Overfrequency (LFSM-O)

ECC.6.3.7.1.1 Each **Power Generating Module** (including **DC Connected Power Park Modules**) and **HVDC Systems** shall be capable of reducing **Active Power** output in response to **Frequency** on the **Total System** when this rises above 50.4Hz. For the avoidance of doubt, the provision of this reduction in **Active Power** output is not an **Ancillary Service**. Such provision is known as **Limited High Frequency Response**. The **Power Generating Module** (including **DC Connected Power Park Modules**) or **HVDC Systems** shall be capable of operating stably during **LFSM-O** operation. However for a **Power Generating Module** (including **DC Connected Power Park Modules**) or **HVDC Systems** operating in **Frequency Sensitive Mode** the requirements of LFSM-O shall apply when the frequency exceeds 50.5Hz.

ECC.6.3.7.1.2 (i) The rate of change of **Active Power** output must be at a minimum a rate of 2 percent of output per 0.1 Hz deviation of **System Frequency** above 50.4Hz (ie a **Droop** of 10%) as shown in Figure ECC.6.3.7.1 below. This would not preclude a **EU Generator** or **HVDC System Owner** from designing their **Power Generating Module** with a **Droop** of less than 10% but in all cases the **Droop** should be 2% or greater~~.~~.

(ii) The reduction in **Active Power** output must be continuously and linearly proportional, as far as is practicable, to the excess of **Frequency** above 50.4 Hz and must be provided increasingly with time over the period specified in (iii) below.

(iii) As much as possible of the proportional reduction in **Active Power** output must result from the frequency control device (or speed governor) action and must be achieved within 10 seconds of the time of the **Frequency** increase above 50.4 Hz. The **Power Generating Module** (including **DC Connected Power Park Modules**) or **HVDC Systems** shall be capable of initiating a power **Frequency** response with an initial delay that is as short as possible. If the delay exceeds 2 seconds the **EU Generator** or **HVDC System Owner** shall justify the ~~delay~~variation, providing technical evidence to **NGET**.

(iv) The residue of the proportional reduction in **Active Power** output which results from automatic action of the **Power Generating Module** (including **DC Connected Power Park Modules**) or **HVDC System** output control devices other than the frequency control devices (or speed governors) must be achieved within 3 minutes for the time of the **Frequency** increase above 50.4Hz.

(v) For the avoidance of doubt, the **LFSM-O** response must be reduced when the **Frequency** falls again and, when to a value less than 50.4Hz, as much as possible of the increase in **Active Power** must be achieved within 10 seconds.

~~(iv)~~(vi) For Ty**pe A** and **Type B Power Generating Modules** which are not required to have **Frequency Sensitive Mode (FSM)** as described in ECC.6.3.7.3 for deviations in **Frequency** up to 50.9Hz at least half of the proportional reduction in **Active Power** output must be achieved in 10 seconds of the time of the **Frequency** increase above 50.4 Hz. For deviations in **Frequency** beyond

50.9Hz the measured rate of change of **Active Power** reduction must exceed 0.5%/sec of the initial output. The **LFSM-O** response must be reduced when the **Frequency** subsequently falls again and, when to a value less than 50.4Hz, at least half the increase in **Active Power** must be achieved in 10 seconds. For a **Frequency** excursion returning from beyond 50.9Hz the measured rate of change of **Active Power** increase must exceed 0.5%/second.

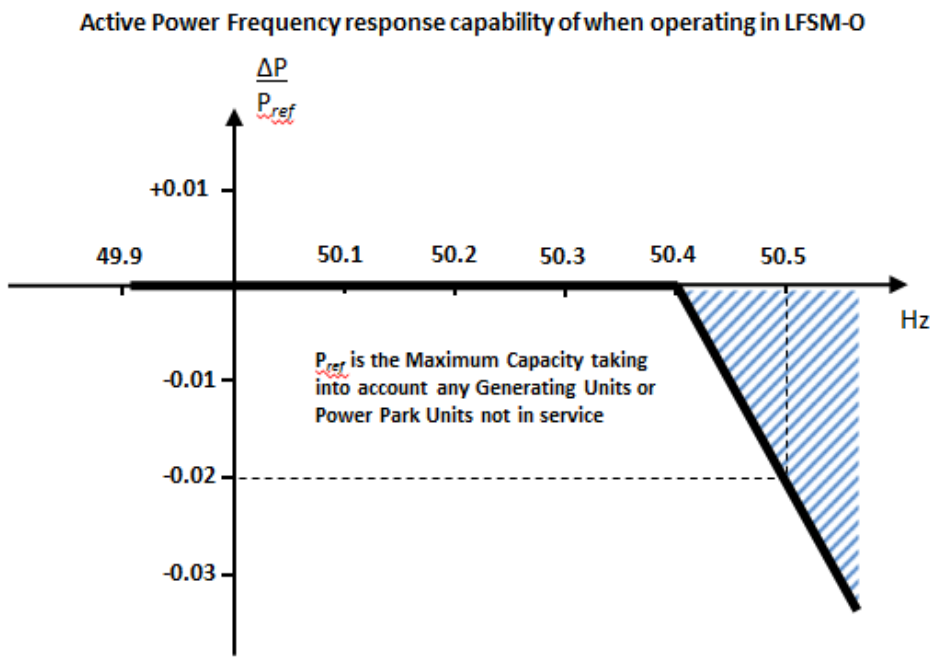

Figure ECC.6.3.7.1 – P_{ref} is the reference **Active Power** to which ΔP is related and ΔP is the change in **Active Power** output from the **Power Generating Module** (including **DC Connected Power Park Modules**) or **HVDC System**. The **Power Generating Module** (including **DC Connected Power Park Modules** or **HVDC Systems)** has to provide a negative **Active Power** output change with a droop of 10% or less based on Pref.

ECC.6.3.7.1.3 Each **Power Generating Module** (including **DC Connected Power Park Modules**) or **HVDC Systems** which is providing **Limited High Frequency Response (LFSM-O)** must continue to provide it until the **Frequency** has returned to or below 50.4Hz or until otherwise instructed by **NGET**. **EU Generators** in respect of **Gensets** and **HVDC Converter Station Owners** in respect of an **HVDC System** should also be aware of the requirements in BC.3.7.2.2.

ECC.6.3.7.1.4 Steady state operation below the **Minimum Stable Operating Level** in the case of **Power Generating Modules** including **DC Connected Power Park Modules** or **Minimum Active Power Transmission Capacity** in the case of **HVDC Systems** is not expected but if **System** operating conditions cause operation below the **Minimum Stable Operating Level** or **Minimum Active Power Transmission Capacity** which could give rise to operational difficulties for the **Power Generating Module** including a **DC Connected Power Park Module** or **HVDC Systems** then the **EU Generator** or HV**DC System Owner** shall be able to return the output of the **Power Generating Module** including a **DC Connected Power Park Module** to an output of not less than the

Minimum Stable Operating Level or **HVDC System** to an output of not less than the **Minimum Active Power Transmission Capacity**.

ECC.6.3.7.1.5 All reasonable efforts should in the event be made by the **EU Generator** or **HVDC System Owner** to avoid such tripping provided that the **System Frequency** is below 52Hz in accordance with the requirements of ECC.6.1.2. If the **System Frequency** is at or above 52Hz, the requirement to make all reasonable efforts to avoid tripping does not apply and the **EU Generator** or **HVDC System Owner** is required to take action to protect its **Power Generating Modules** including **DC Connected Power Park Modules** or **HVDC Converter Stations**.

ECC.6.3.7.2 Limited Frequency Sensitive Mode – Underfrequency (LFSM-U)

ECC.6.3.7.2.1 Each **Type C Power Generating Module** and **Type D Power Generating Module** (including **DC Connected Power Park Modules**) or **HVDC Systems** operating in **Limited Frequency Sensitive Mode** shall be capable of increasing **Active Power** output in response to **System Frequency** when this falls below 49.5Hz. For the avoidance of doubt, the provision of this increase in **Active Power** output is not a mandatory **Ancillary Service** and it is not anticipated **Power Generating Modules** (including **DC Connected Power Park Modules**) or **HVDC Systems** are operated in an inefficient mode to facilitate delivery of **LFSM-U** response, but any inherent capability (where available) should be made without undue delay. The **Power Generating Module** (including **DC Connected Power Park Modules**) or **HVDC Systems** shall be capable of stable operation during **LFSM-U Mode**. For example, a **EU Generator** which is operating with no headroom (eg it is operating at maximum output or is de-loading as part of a run down sequence and has no headroom) would not be required to provide **LFSM-U**.

ECC.6.3.7.2.2 (i) The rate of change of **Active Power** output must be at a minimum a rate of 2 percent of output per 0.1 Hz deviation of **System Frequency** below 49.5Hz (ie a **Droop** of 10%) as shown in Figure ECC.6.3.7.2.2 below. This requirement only applies if the **Power Generating Module** has headroom and the ability to increase **Active Power** output. In the case of a **Power Park Module** or **DC Connected Power Park Module** the requirements of Figure ECC.6.3.7.2.2 shall be reduced pro-rata to the amount of **Power Park Units** in service and available to generate. For the avoidance of doubt, this would not preclude an **EU Generator** or **HVDC System Owner** from designing their **Power Generating Module** with a lower **Droop** setting, for example between 3 – 5%.

(ii) As much as possible of the proportional increase in **Active Power** output must result from the **Frequency** control device (or speed governor) action and must be achieved for **Frequencies** below 49.5 Hz. The **Power Generating Module** (including **DC Connected Power Park Modules**) or **HVDC Systems** shall be capable of initiating a power **Frequency** response with minimal delay. If the delay exceeds 2 seconds the **EU Generator** or HV**DC System Owner** shall justify the delay, providing technical evidence to **NGET***)*.

(iii) The actual delivery of **Active Power Frequency Response** in **LFSM-U** mode shall take into account

The ambient conditions when the response is to be triggered

The operating conditions of the **Power Generating Module** (including **DC Connected Power Park Modules**) or **HVDC Systems** in particular limitations on operation near **Maximum Capacity** or **Maximum HVDC Active Power Transmission Capacity** at low frequencies and the respective impact of ambient conditions as detailed in ECC.6.3.3.

The availability of primary energy sources.

(iv) In **LFSM_U Mode**, the **Power Generating Module** (including **DC Connected Power Park Modules**) and **HVDC Systems**, shall be capable of providing a power increase up to its **Maximum Capacity** or **Maximum HVDC Active Power Transmission Capacity** (as applicable).

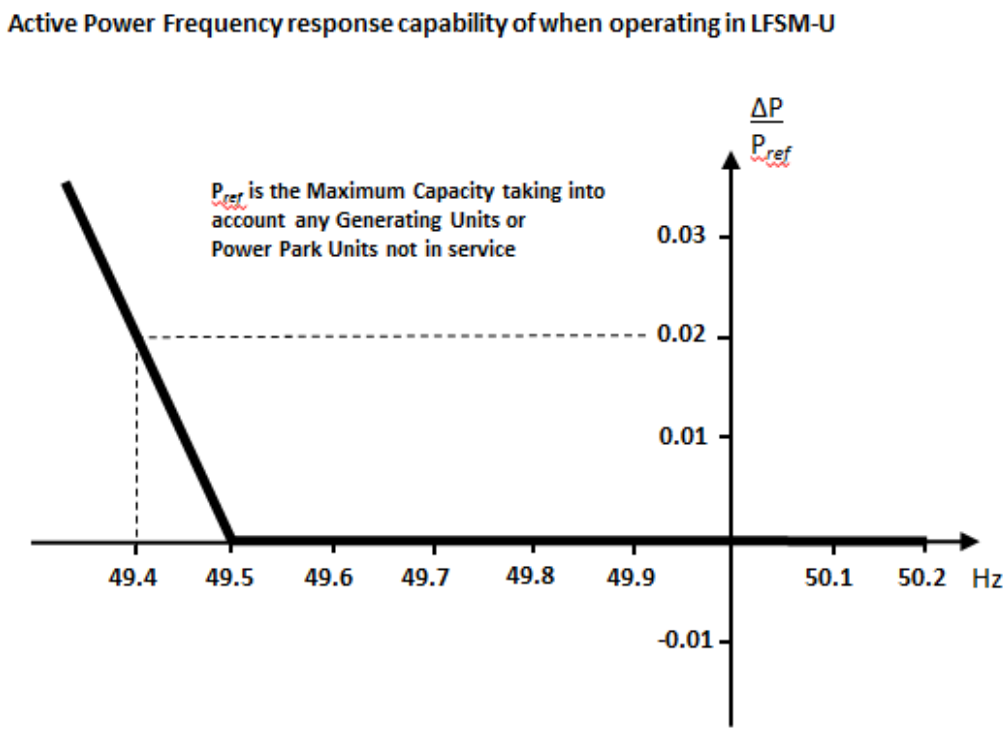

Figure ECC.6.3.7.2.2 – P_{ref} is the reference **Active Power** to which ΔP is related and ΔP is the change in **Active Power** output from the **Power Generating Module** (including **DC Connected Power Park Modules**) or **HVDC System**. The **Power Generating Module** (including **DC Connected Power Park Modules** or **HVDC Systems)** has to provide a positive **Active Power** output change with a droop of 10% or less based on Pref.

ECC.6.3.7.3 Frequency Sensitive Mode – (FSM)

ECC.6.3.7.3.1 In addition to the requirements of ECC.6.3.7.1 and ECC.6.3.7.2 each **Type C Power Generating Module** and **Type D Power Generating Module** (including **DC Connected Power Park Modules**) or **HVDC Systems** must be fitted with a fast acting proportional **Frequency** control device (or turbine speed governor) and unit load controller or equivalent control device to provide **Frequency** response under normal operational conditions in accordance with **Balancing Code 3** (**BC3**). In the case of a **Power Park Module** including a **DC Connected Power Park Module**, the **Frequency** or speed control device(s) may be on the **Power Park Module** (including a **DC Connected Power Park Module**) or on each individual **Power Park Unit** (including a **Power Park Unit** within a **DC Connected Power Park Module**) or be a combination of both. The **Frequency** control device(s) (or speed governor(s)) must be designed and operated to the appropriate:

(i) **European Specification**: or

(ii) in the absence of a relevant **European Specification**, such other standard which is in common use within the European Community (which may include a manufacturer specification);

as at the time when the installation of which it forms part was designed or (in the case of modification or alteration to the **Frequency** control device (or turbine speed governor)) when the modification or alteration was designed.

The **European Specification** or other standard utilised in accordance with sub paragraph ECC.6.3.7.3.1 (a) (ii) will be notified to **NGET** by the **EU Generator** or **HVDC System Owner**:

(i) as part of the application for a **Bilateral Agreement**; or

(ii) as part of the application for a varied **Bilateral Agreement**; or

(iii) in the case of an Embedded Development, within 28 days of entry into the Embedded Development Agreement (or such later time as agreed with **NGET**) or

(iv) as soon as possible prior to any modification or alteration to the **Frequency** control device (or governor); and

ECC.6.3.7.3.2 The **Frequency** control device (or speed governor) in co-ordination with other control devices must control each **Type C Power Generating Module** and **Type D Power Generating Module** (including **DC Connected Power Park Modules**) or **HVDC Systems Active Power Output** or **Active Power** transfer capability with stability over the entire operating range of the **Power Generating Module** (including **DC Connected Power Park Modules**) or **HVDC Systems**; and

ECC.6.3.7.3.3 **Type C** and **Type D Power Generating Modules** and **DC Connected Power Park Modules** shall also meet the following minimum requirements:

(i) capable of providing **Active Power Frequency** response in accordance with the performance characteristic shown in Figure 6.3.7.3.3(a) and parameters in Table 6.3.7.3.3(a)

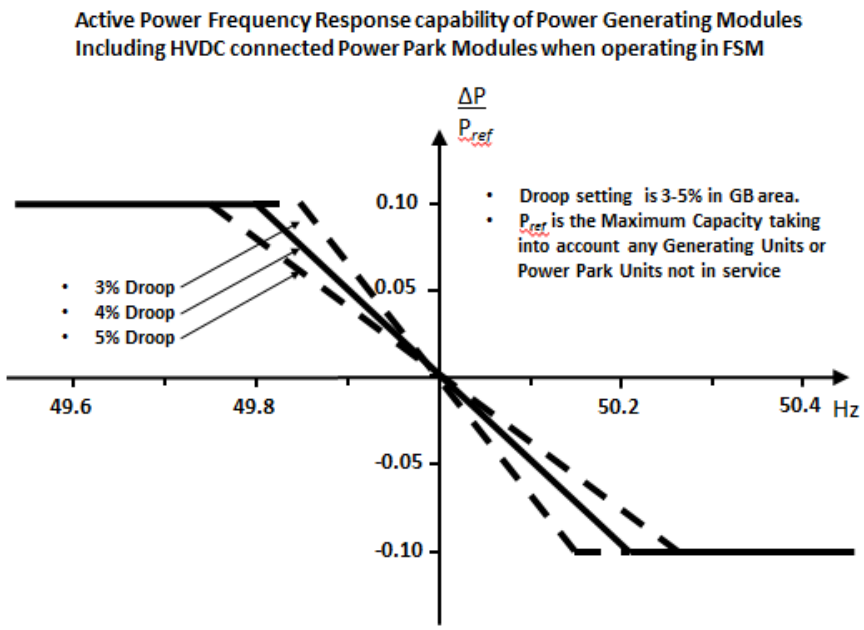

Figure 6.3.7.3.3(a) – **Frequency Sensitive Mode** capability of **Power Generating Modules** and **DC Connected Power Park Modules**

Parameter	Setting
Nominal **System Frequency**	50Hz
Active Power as a percentage of **Maximum Capacity** ($\frac{\lvert \Delta P_1 \rvert}{P_{max}}$)	10%
Frequency Response Insensitivity in mHz ($\lvert \Delta f_i \rvert$)	±15mHz
Frequency Response Insensitivity as a percentage of nominal frequency ($\frac{\lvert \Delta f_i \rvert}{f_n}$)	±0.03%
Frequency Response Deadband in mHz	0 (mHz)
Droop (%)	3 – 5%

Table 6.3.7.3.3(a) – Parameters for **Active Power Frequency** response in **Frequency Sensitve Mode** including the mathematical expressions in Figure 6.3.7.3.3(a).

(ii) In satisfying the performance requirements specified in ECC.6.3.7.3(i) **EU Generators** in respect of each **Type C** and **Type D Power Generating Modules and DC Connected Power Park Module** should be aware:-

in the case of overfrequency, the **Active Power Frequency** response is limited by the **Minimum Regulating Level**,

in the case of underfrequency, the **Active Power Frequency** response is limited by the **Maximum Capacity,**

the actual delivery of **Active Power** frequency response depends on the operating and ambient conditions of the **Power Generating Module** (including **DC Connected Power Park Modules**) when this response is triggered, in particular limitations on operation near **Maximum Capacity** at low **Frequencies** as specified in ECC.6.3.3 and available primary energy sources.

The frequency control device (or speed governor) must also be capable of being set so that it operates with an overall speed **Droop** of between 3 – 5%. The **Frequency Response Deadband** and **Droop** must be able to be reselected repeatedly. For the avoidance of doubt, in the case of a **Power Park Module** (including **DC Connected Power Park Modules**) the speed **Droop** should be equivalent of a fixed setting between 3% and 5% applied to each **Power Park Unit** in service.

(iii) In the event of a **Frequency** step change, each **Type C** and **Type D Power Generating Module** and **DC Connected Power Park Module** shall be capable of activating full and stable **Active Power Frequency** response (without undue power oscillations), in accordance with the performance characteristic shown in Figure 6.3.7.3.3(b) and parameters in Table 6.3.7.3.3(b).

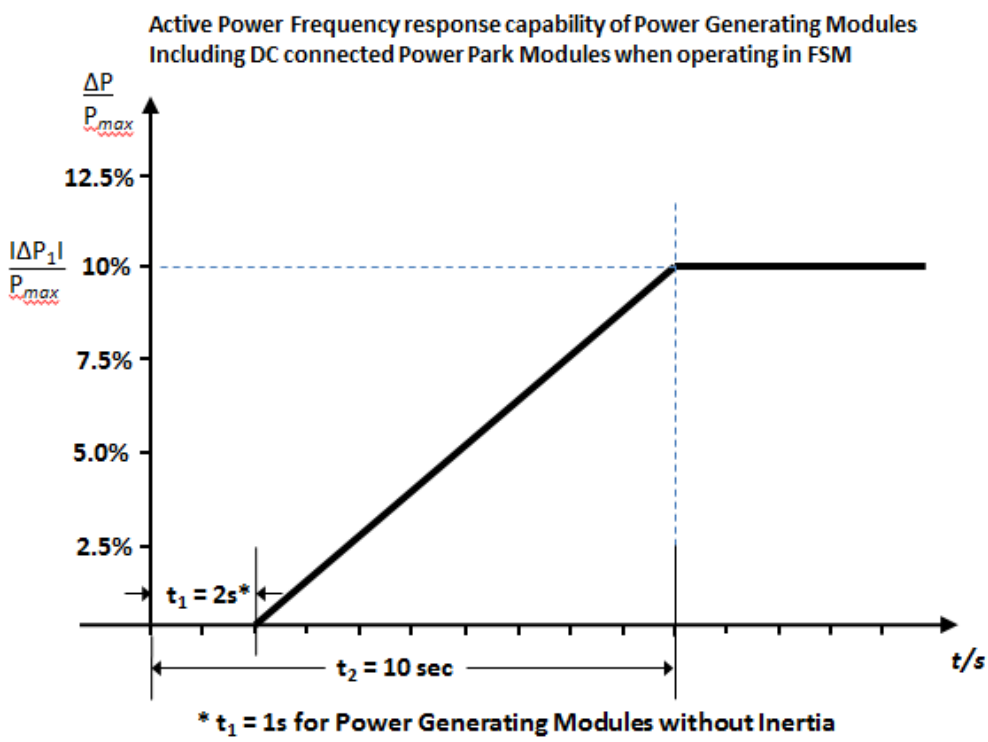

Figure 6.3.7.3.3(b) **Active Power Frequency Response** capability.

Parameter	Setting

Active Power as a percentage of **Maximum Capacity (frequency response range)** ($\frac{\lvert\Delta P_1\rvert}{P_{max}}$)	10%
Maximum admissible initial delay t_1 for **Power Generating Modules** (including **DC Connected Power Park Modules**) with inertia unless justified as specified in ECC.6.3.7.3.3 (iv)	2 seconds
Maximum admissible initial delay t_1 for **Power Generating Modules** (including **DC Connected Power Park Modules**) which do not contribute to **System** inertia unless justified as specified in ECC.6.3.7.3.3 (iv)	1 second
Activation time t_2	10 seconds

Table 6.3.7.3.3(b) – Parameters for full activation of **Active Power Frequency** response resulting from a **Frequency** step change. Table 6.3.7.3.3(b) also includes the mathematical expressions used in Figure 6.3.7.3.3(b).

(iv) The initial activation of **Active Power Primary Frequency** response shall not be unduly delayed. For **Type C** and **Type D Power Generating Modules** (including **DC Connected Power Park Modules**) with inertia the delay in initial **Active Power Frequency** response shall not be greater than 2 seconds. For **Type C** and **Type D Power Generating Modules** (including **DC Connected Power Park Modules**) without inertia, the delay in initial **Active Power Frequency** response shall not be greater than 1 second. If the **Generator** cannot meet this requirement they shall provide technical evidence to **NGET** demonstrating why a longer time is needed for the initial activation of **Active Power Frequency** response.

(v) in the case of **Type C** and **Type D Power Generating Modules** (including **DC Connected Power Park Modules**) other than the **Steam Unit** within a **CCGT Module** the combined effect of the **Frequency Response Insensitivity** and **Frequency Response Deadband** of the **Frequency** control device (or speed governor) should be no greater than 0.03Hz (for the avoidance of doubt, ±0.015Hz). In the case of the **Steam Unit** within a **CCGT Module**, the **Frequency Response Deadband** should be set to an appropriate value consistent with the requirements of ECC.6.3.7.3.5(ii) and the requirements of BC3.7.2.2 for the provision of **LFSM-O** taking account of any **Frequency Response Insensitivity** of the Frequency control device (or speed governor);

ECC.6.3.7.3.4 **HVDC Systems** shall also meet the following minimum requirements:

(i) **HVDC Systems** shall be capable of responding to **Frequency** deviations in each connected AC **System** by adjusting their **Active Power** import or export as shown in Figure 6.3.7.3.4(a) with the corresponding parameters in Table 6.3.7.3.4(a).

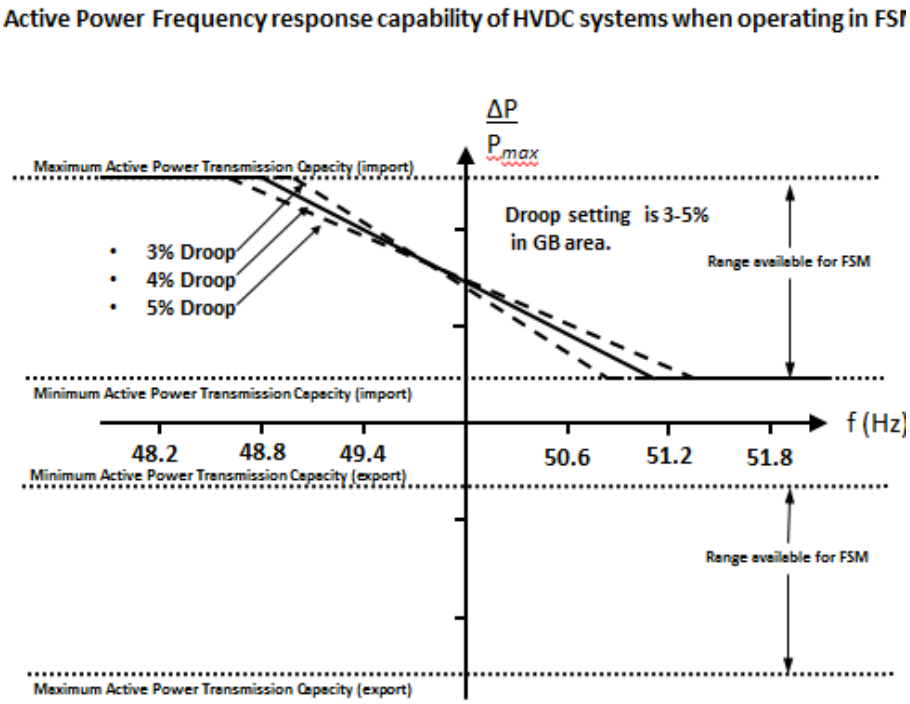

Figure 6.3.7.3.4(a) – **Active Power** frequency response capability of a **HVDC System** operating in **Frequency Sensitive Mode** (FSM). ΔP is the change in active power output from the **HVDC System**..

Parameter	Setting
Frequency Response Deadband	0
Droop S1 and S2 (upward and downward regulation) where S1=S2.	3 – 5%
Frequency Response Insensitivity	±15mHz

Table 6.3.7.3.4(a) – Parameters for **Active Power Frequency** response in **FSM** including the mathematical expressions in Figure 6.3.7.3.4.

(ii) Each **HVDC System** shall be capable of adjusting the **Droop** for both upward and downward regulation and the **Active Power** range over which **Frequency Sensitive Mode** of operation is available as defined in ECC.6.3.7.3.4.

(iii) In addition to the requirements in ECC.6.3.7.4(i) and ECC.6.3.7.4(ii) each **HVDC System** shall be capable of:-

delivering the response as soon as technically feasible

delivering the response on or above the solid line in Figure 6.3.7.3.4(b) in accordance with the parameters shown in Table 6.3.7.3.4(b)

initiating the delivery of **Primary Response** in no less than 0.5 seconds unless otherwise agreed with **NGET**. Where the initial delay time (t_1 – as shown in Figure 6.3.7.3.4(b)) is longer than 0.5 seconds the **HVDC Converter Station Owner** shall reasonably justify it to **NGET**.

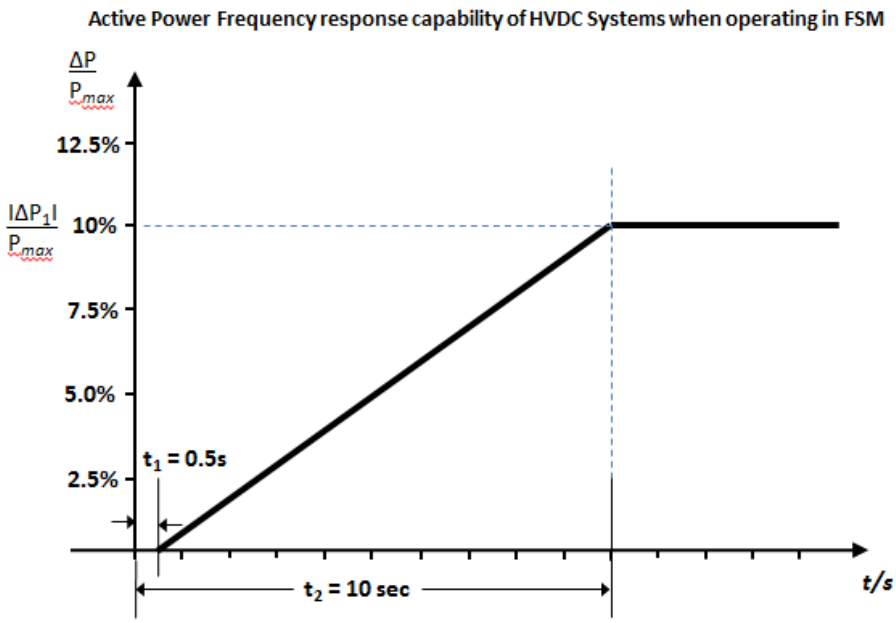

Figure 6.3.7.3.4(b) **Active Power Frequency Response** capability of a **HVDC System**. ΔP is the change in **Active Power** triggered by the step change in frequency

Parameter	Setting
Active Power as a percentage of **Maximum Capacity (frequency response range)** ($\frac{\lvert\Delta P_1\rvert}{P_{max}}$)	10%
Maximum admissible delay t_1	0.5 seconds
Maximum admissible time for full activation t_2, unless longer activation times are agreed with **NGET**	10 seconds

Table 6.3.7.3.4(b) – Parameters for full activation of **Active Power Frequency** response resulting from a **Frequency** step change.

(iv) For **HVDC Systems** connecting various **Synchronous Areas**, each **HVDC System** shall be capable of adjusting the full **Active Power Frequency Response** when operating in **Frequency Sensitive Mode** at any time and for a continuous time period. In addition, the **Active Power** controller of each **HVDC System** shall not have any adverse impact on the delivery of frequency response.

ECC.6.3.7.3.5 For **HVDC Systems** and **Type C** and **Type D Power Generating Modules** (including **DC Connected Power Park Modules**), other than the **Steam Unit** within a **CCGT Module** the combined effect of the **Frequency Response Insensitivity** and **Frequency Response Deadband** of the **Frequency** control device (or speed governor) should be no greater than 0.03Hz (for the avoidance of doubt, ±0.015Hz). In the case of the **Steam Unit** within a **CCGT Module**, the **Frequency Response Deadband** should be set to an appropriate value consistent with the requirements of ECC.6.3.7.3.5(ii) and the requirements of BC3.7.2.2 for the provision of **LFSM-O** taking account of any **Frequency Response Insensitivity** of the **Frequency** control device (or speed governor);

(i) With regard to disconnection due to underfrequency, **EU Generators** responsible for **Type C** and **Type D Power Generating Modules** (including **DC Connected Power Park Modules**) capable of acting as a load, including but not limited to **Pumped Storage** and tidal **Power Generating Modules**, **HVDC Systems** and **Remote End HVDC Converter Stations**, shall be capable of disconnecting their load in case of underfrequency which will be agreed with **NGET**. For the avoidance of doubt this requirement does not apply to station auxiliary supplies; **EU Generators** in respect of **Type C** and **Type D Pumped Storage Power Generating Modules** should also be aware of the requirements in OC.6.6.6.

(ii) Where a **Type C** or **Type D Power Generating Module**, **DC Connected Power Park Module** or **HVDC System** becomes isolated from the rest of the **Total System** but is still supplying **Customers**, the **Frequency** control device (or speed governor) must also be able to control **System Frequency** below 52Hz unless this causes the **Type C** or **Type D Power Generating Module** or **DC Connected Power Park Module** to operate below its **Minimum Regulating Level** or **Minimum Active Power Transmission Capacity** when it is possible that it may, as detailed in BC 3.7.3, trip after a time. For the avoidance of doubt **Power Generating Modules** (including **DC Connected Power Park Modules**) and **HVDC Systems** are only required to operate within the **System Frequency** range 47 - 52 Hz as defined in ECC.6.1.2 and for converter based technologies, the remaining island contains sufficient fault level for effective commutation;

(iii) Each **Type C** and **Type D Power Generating Module** and **HVDC Systems** shall have the facility to modify the **Target Frequency** setting either continuously or in a maximum of 0.05Hz steps over at least the range 50 ±0.1Hz should be provided in the unit load controller or equivalent device.

ECC.6.3.7.3.6 In addition to the requirements of ECC.6.3.7.3 each **Type C** and **Type D Power Generating Module** and **HVDC System** shall be capable of meeting the minimum **Frequency** response requirement profile subject to and in accordance with the provisions of Appendix A3.

ECC.6.3.7.3.7 For the avoidance of doubt, the requirements of Appendix A3 do not apply to **Type A** and **Type B Power Generating Modules**.

Figure 11.1 Change in Active Power with falling frequency

11.2.3.2 For the avoidance of doubt in the case of a **Power Generating Module** using an **Intermittent Power Source** where the power input will not be constant over time, the requirement is that the **Active Power** output shall be independent of system frequency under (a) above and should not drop with system frequency by greater than the amount specified in (b) above.

11.2.4 **Limited Frequency Sensitive Mode – Over frequency**

11.2.4.1 Each **Power Generating Module** shall be capable of reducing **Active Power** output in response to frequency on the **Total System** when this rises above 50.4 Hz. The **Power Generating Module** shall be capable of operating stably during **LFSM-O** operation. If a **Power Generating Module** has been contracted to operate in **Frequency Sensitive Mode** the requirements of **LFSM-O** shall apply when frequency exceeds 50.5 Hz.

(a) The rate of change of **Active Power** output must be at a minimum a rate of 2% of output per 0.1 Hz deviation of system frequency above 50.4 Hz (ie a **Droop** of 10%) as shown in Figure 11.2. For the avoidance of doubt, this would not preclude a **Generator** from designing their **Power Generating Module** with a **Droop** of less than 10%, but in all cases the **Droop** should be 2% or greater.

(b) The **Power Generating Module** shall be capable of initiating a power frequency response with an initial delay that is as short as possible. If the initial delay exceeds 2 s the **Generator** shall justify the delay, providing technical evidence to the **DNO**, who will pass this evidence to the **NETSO**.

(c) For deviations in frequency up to 50.9 Hz at least half of the proportional reduction in **Active Power** output ~~As much as possible of the proportional reduction in **Active Power** output must result from the frequency control device (or speed governor) action and must be achieved~~ within 10 s of the time of the frequency increase above 50.4 Hz.

(d) For deviations in frequency beyond 50.9 Hz the measured rate of change of **Active Power** reduction must exceed 0.5%/s of the initial output.

~~(b)~~(e) The **LFSM-O** response must be reduced when the frequency subsequently falls again and, when to a value less than 50.4 Hz, at least half the increase in **Active Power** must be achieved in 10 seconds. For a frequency excursion returning from beyond 50.9 Hz the measured rate of change of **Active Power** increase must exceed 0.5%/s.

~~(c)~~(f) If the reduction in **Active Power** is such that the **Power Generation Modul**e reaches its **Minimum Generation**, it must continue to operate stably at this level.

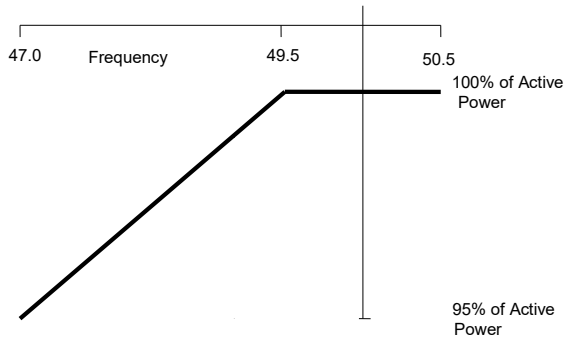

Figure 12.1 Change in Active Power with falling frequency

12.2.3.2 For the avoidance of doubt in the case of a **Power Generating Module** using an **Intermittent Power Source** where the power input will not be constant over time, the requirement is that the **Active Power** output shall be independent of system frequency under (a) above and should not drop with system frequency by greater than the amount specified in (b) above.

12.2.4 **Limited Frequency Sensitive Mode – Over frequency**

12.2.4.1 Each **Power Generating Module** shall be capable of reducing **Active Power** output in response to frequency on the **Total System** when this rises above 50.4 Hz. The **Power Generating Module** shall be capable of operating stably during **LFSM-O** operation. If a **Power Generating Module**, has been contracted to operate in **Frequency Sensitive Mode** the requirements of **LFSM-O** shall apply when frequency exceeds 50.5 Hz.

(a) The rate of change of **Active Power** output must be at a minimum a rate of 2% of output per 0.1 Hz deviation of system frequency above 50.4 Hz (ie a **Droop** of 10%) as shown in Figure 12.2. For the avoidance of doubt, this would not preclude a **Generator** from designing their **Power Generating Module** with a **Droop** of less than 10%, but in all cases the **Droop** should be 2% or greater.

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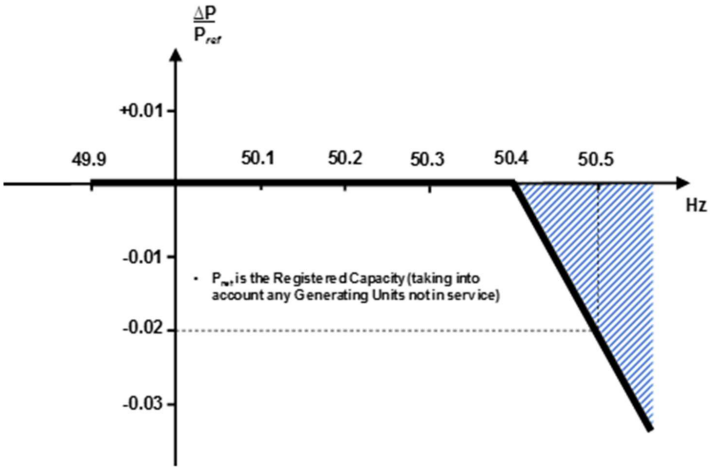
~~(a)~~(b) The **Power Generating Module** shall be capable of initiating a power frequency response with an initial delay that is as short as possible. If the initial delay exceeds 2 s the **Generator** shall justify the delay, providing technical evidence to the **DNO**, who will pass this evidence to the **NETSO**.

~~(b)~~(c) For deviations in frequency up to 50.9 Hz at least half of the proportional reduction in **Active Power** output ~~As much as possible of the proportional reduction in **Active Power** output must result from the frequency control device (or speed governor) action and~~ must be achieved within 10 s of the time of the frequency increase above 50.4 Hz. ~~The **Power Generating Module** shall be capable of initiating a power frequency response with an initial delay that is as short as possible. If the initial delay exceeds 2 s the **Generator** shall justify the delay, providing technical evidence to the **DNO**, who will pass this evidence to the **NETSO**.~~

(d) For deviations in frequency beyond 50.9 Hz the measured rate of change of **Active Power** reduction must exceed 0.5%/s of the initial output.

(e) The **LFSM-O** response must be reduced when the frequency subsequently falls again and, when to a value less than 50.4 Hz, at least half the increase in **Active Power** must be achieved in 10 seconds. For a frequency excursion returning from beyond 50.9 Hz the measured rate of change of **Active Power** increase must exceed 0.5%/s of the **Active Power.**

~~(e)~~(f) If the reduction in **Active Power** is such that the **Power Generation Module** reaches its **Minimum Generation**, it must continue to operate stably at this level.



P_{ref} is the reference **Active Power** to which ΔP is related and. ΔP is the change in **Active Power** output from the **Power Generating Module**.

Figure 12.2 Active Power Frequency Response capability when operating in LFSM-O

12.2.4.2 When the **Power Generating Module** is providing **Limited Frequency Sensitive Mode Over frequency (LFSM-O)** response it must continue to provide the frequency response until the frequency has returned to or is below 50.4 Hz.

12.2.4.3 Steady state operation below **Minimum Generation** is not expected but if system operating conditions cause operation below **Minimum Generation** which give rise to operational difficulties then the **Generator** shall be able to return the output of the **Power Generating Module** to an output of not less than the **Minimum Generation.**

12.3 Fault Ride Through and Phase Voltage Unbalance

12.3.1 Paragraphs 12.3.1.1 to 12.3.1.7 inclusive set out the fault ride through, principles and concepts applicable to **Synchronous Power Generating Modules** and **Power Park Modules**, subject to disturbances from faults on the **Network** up to 140 ms in duration.

12.3.1.1 Each **Synchronous Power Generating Module** and **Power Park Module** is required to remain connected and stable for any balanced and unbalanced fault

not trip during this test.

The results shall be recorded on the test sheet of Annex A.2-1.

A.7.2.3 Power Output with Falling Frequency

The **Generator** will propose and agree a test procedure with the **DNO**, which will demonstrate how the **Synchronous Power Generating Module Active Power** output responds to changes in system frequency.

The tests can be undertaken by the **Synchronous Power Generating Module** powering a suitable load bank, or alternatively using the test set up of Figure A8.6. In both cases a suitable test could be to start the test at nominal frequency with the **Synchronous Power Generating Module** operating at 100% of its **Registered Capacity**.

The frequency should then be set to 49.5 Hz for 5 minutes. The output should remain at 100% of **Registered Capacity**.

The frequency should then be set to 49.0 Hz and once the output has stabilised, held at this frequency for 5 minutes. The **Active Power** output must not be below 99% of **Registered Capacity**.

The frequency should then be set to 48.0 Hz and once the output has stabilised, held at this frequency for 5 minutes. The **Active Power** output must not be below 97% of **Registered Capacity**.

The frequency should then be set to 47.6 Hz and once the output has stabilised, held at this frequency for 5 minutes. The **Active Power** output must not be below 96.2% of **Registered Capacity**.

The frequency should then be set to 47.1 Hz and held at this frequency for 20 s. The **Active Power** output must not be below 95.0% of **Registered Capacity** and the **Synchronous Power Generating Module** must not trip in less than the 20s of the test.

The **Generator** shall inform the **DNO** if any load limiter control is additionally employed.

A.7.2.4 Limited Frequency Sensitive Mode – Over (LFSM-O)

Note that this test is also an alternative to the test in A.7.1.3.

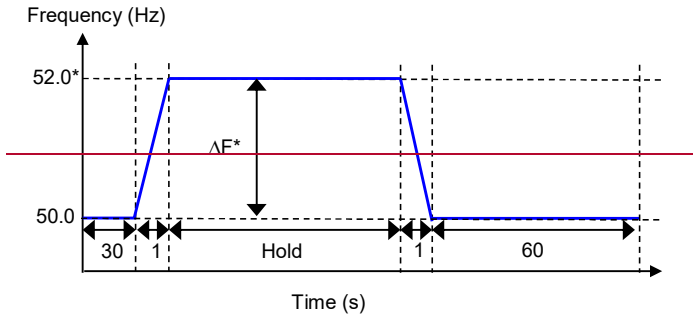
The two frequency response tests in **Limited Frequency Sensitive Mode (LFSM)** to demonstrate **LFSM-O** capability to a frequency injection as shown by Figures A.7.8 and Figures A.7.9 are to be conducted at **Registered Capacity**.

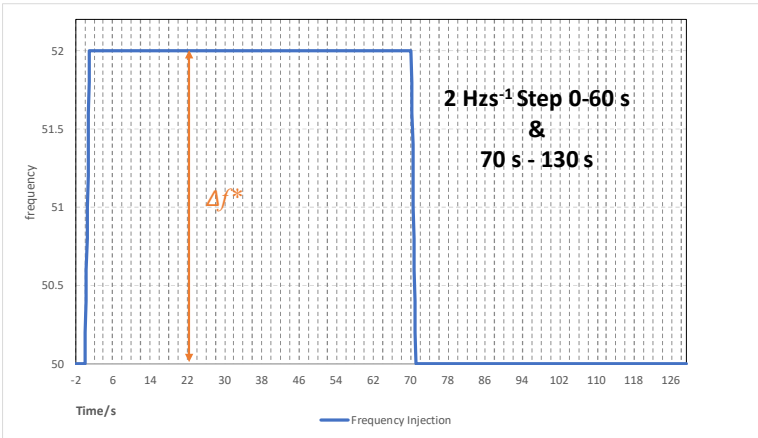
There should be sufficient time allowed between tests for control systems to reach steady state. ~~Where the diagram states 'HOLD' t~~The injection signal should be maintained until the **Active Power** (MW) output of the **Power Generating Module** has stabilised. The **DNO** may require repeat tests should the tests give unexpected results.

The frequency input and t~~T~~he expected **Active Power** response ~~which is~~ are illustrated for different periods from 0 s to 130 s in Figures A.7.~~9~~8 for a step change in frequency and in Figures A.7.~~10~~9 for a ramp change in frequency. This should be in accordance with Section 11.2.4 (a threshold frequency of 50.4 Hz and a **Droop** of 10%) and undamped oscillations should not occur after the step or ramp

frequency change. Note for diagram purposes only a short interval is shown between the frequency increase and decrease for each test. In practice the return step or ramp can start any time after the output has stabilised after the first step or ramp.

The response should commence within 2 s and the response must be to the left of the red line (ie between the green line and the red line), and be as close to the green line as possible, when following the frequency step or ramp. Note that the red line represents the 0.5%/s specified in 11.2.4.1.~~The response should commence within 2 s (or such time as the **DNO** might agree with the **Generator**); ie the response should normally be contained within the blue lines, and as close to the left as possible, when following the frequency ramp. The response should be complete in a reasonable time and the **DNO** can agree with the **Generator** a longer completion time than suggested by the blue lines taking into account the technical capabilities of the **Power Generating Module** and its prime mover.~~





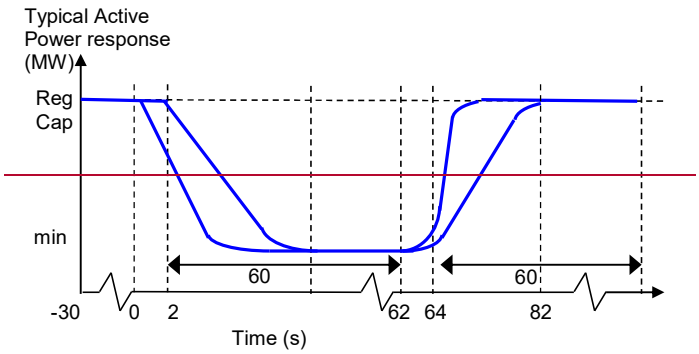


Figure A.7.8(i): LFSM-O step response test – frequency injection

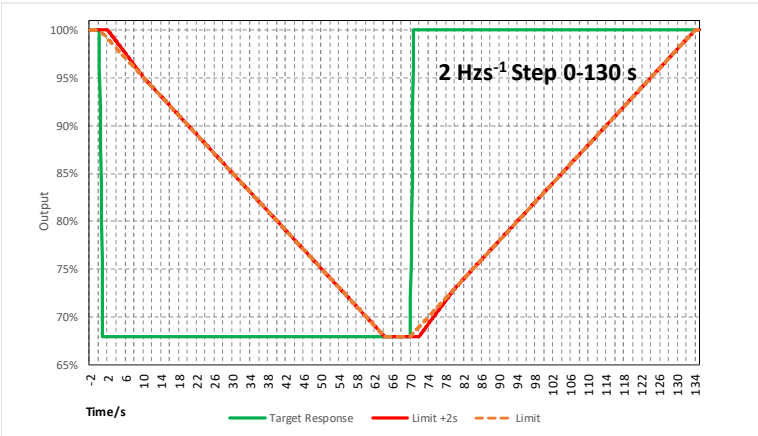


Figure A.7.8(ii): LFSM-O step response test – target response and limits

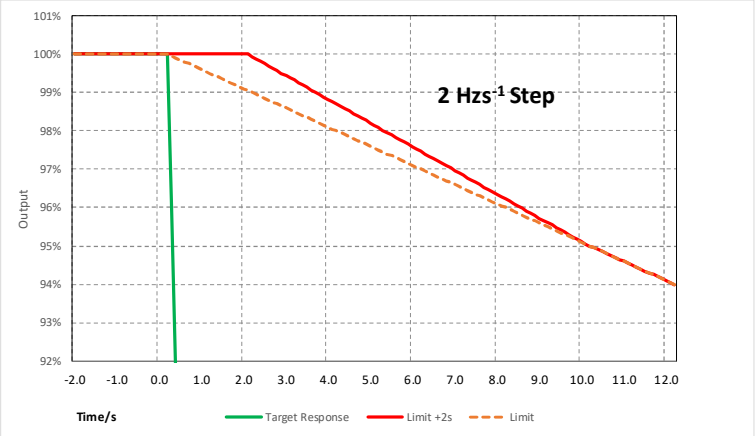


Figure A.7.8(iii): LFSM-O step response test – expansion of the allowed 2 s response delay (frequency increase)

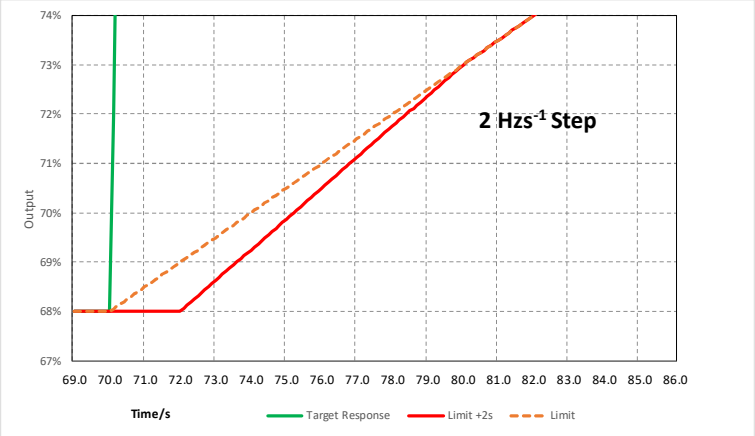


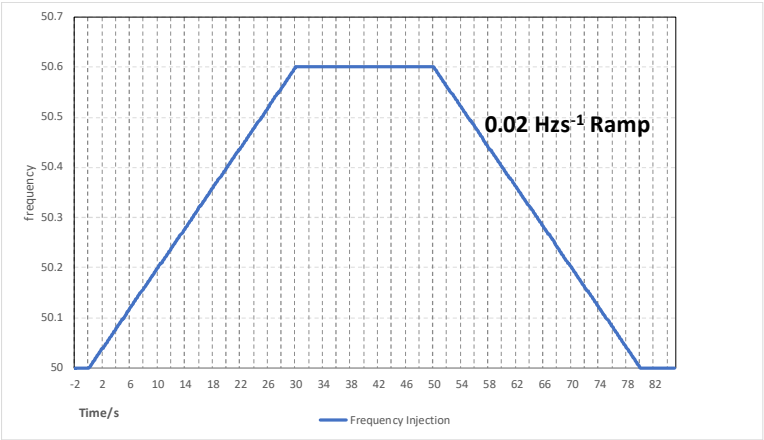
Figure A.7.8(iv): LFSM-O step response test – expansion of the allowed 2 s response delay (frequency decrease)

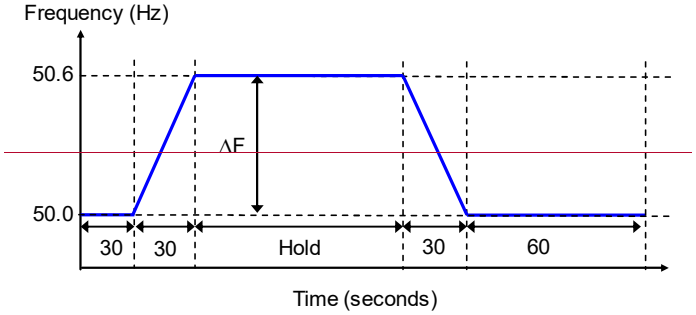
** This frequency step Δf will generally be +2.0 Hz unless an injection of this size causes a reduction in plant output that takes the operating point below **Minimum Generation** in which case an appropriate injection should be calculated in accordance with the following:

For example 1.5 Hz is needed to take an initial output 100% to a final output of 70%. If the initial output is not 100% and the **Minimum Generation** is not 70% then the injected step should be adjusted accordingly as shown in the example given below:

Initial output	100%

Minimum Generation	70%
Frequency controller **Droop**	10%
Frequency to be injected	= (1.00 – 0.70) x 0.1 x 50 = 1.5Hz





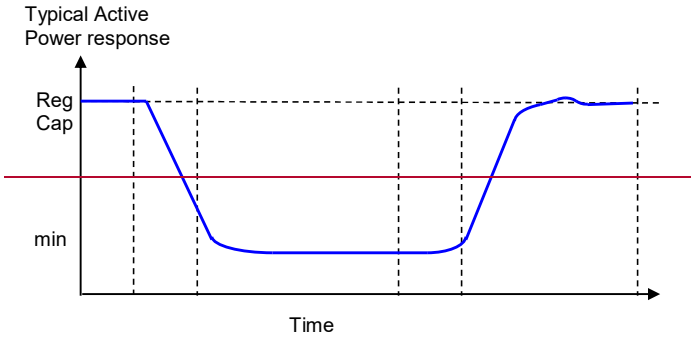


Figure A.7.9(i): LFSM-O ramp response test – frequency injection

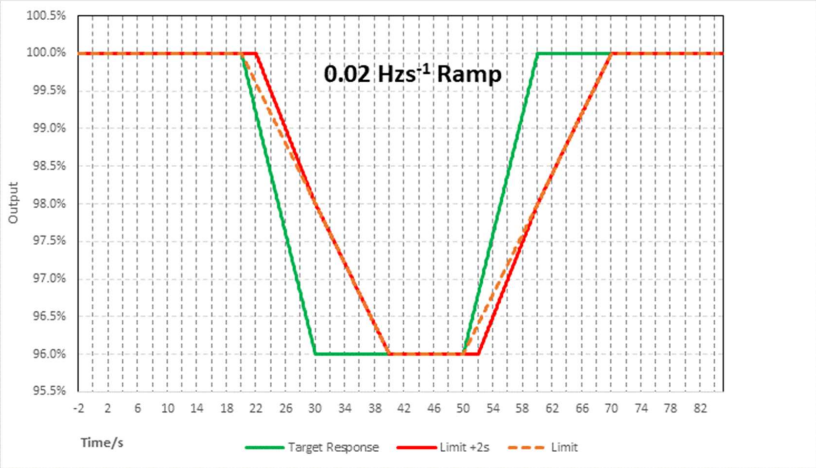


Figure A.7.9(ii): LFSM-O ramp response test – target response and limits

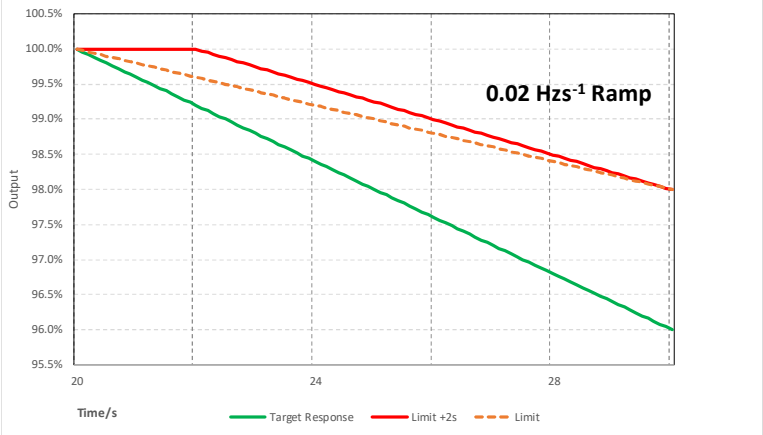


Figure A.7.9(iii): LFSM-O ramp response test – expansion (frequency increase)

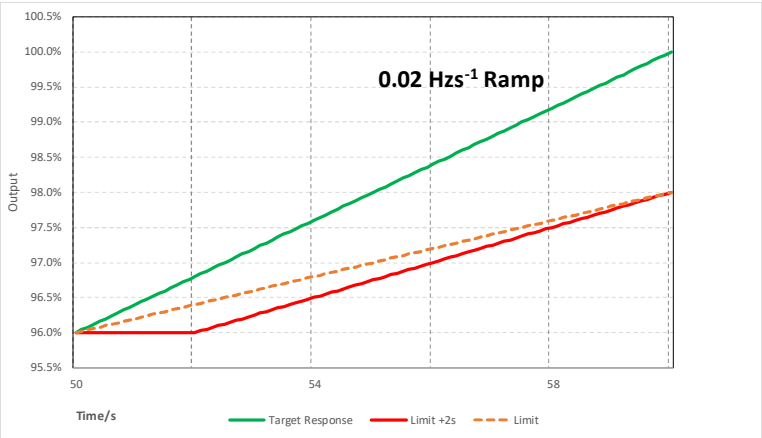


Figure A.7.9(iv): LFSM-O ramp response test – expansion (frequency decrease)

~~**Figure A.7.9: LFSM-O ramp response test**~~

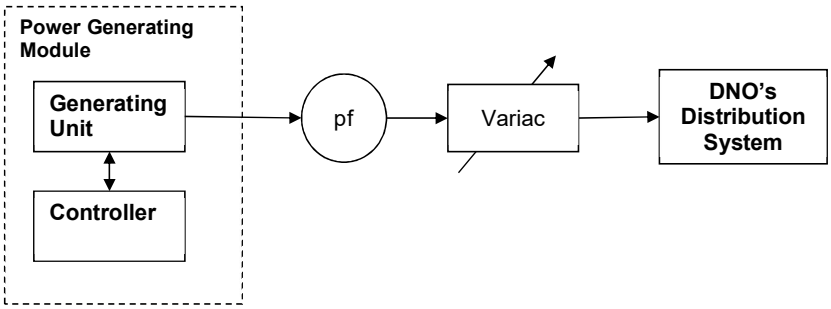
A.7.2.5 Power Quality

A.7.2.5.1 Harmonics

The tests should be carried out as specified in BS EN 61000-3-12 and can be undertaken with a fixed source of energy at two power levels firstly between 45 and 55% and at 100% of maximum export capacity.

A.7.2.5.2 Power Factor

The test set up shall be such that the **Power Generating Module** supplies full load to the **DNO's Distribution Network** via the **Power Factor** (pf) meter and the variac as shown below in Figure A.7.10. The **Power Generating Module** pf should be within the limits given in paragraph 11.1.5, for three test voltages 230 V –6%, 230 V and 230 V +10%.



NOTE 1. For reasons of clarity the points of isolation are not shown

	Generating Unit running at **Registered Capacity** and maximum lagging **Reactive Power**.	
	Over-excitation Limit temporarily set close to this operating point.	
1	• Inject positive voltage step into **AVR** Voltage setpoint and hold • Wait till **Over-excitation Limiter** operates after sufficient time delay to bring back the excitation back to the limit. • Remove step returning **AVR** Voltage setpoint to nominal.	
	Over-excitation Limit restored to its normal operating value.	

B.5.5 Reactive Capability

B.5.5.1 The **Reactive Power** capability on each **Synchronous Power Generating Module** will normally be demonstrated by:

(a) operation of the **Synchronous Power Generating Module** at maximum lagging **Reactive Power** and **Registered Capacity** for 1 hour.

(b) operation of the **Synchronous Power Generating Module** at maximum leading **Reactive Power** and **Registered Capacity** for 1 hour.

(c) operation of the **Synchronous Power Generating Module** at maximum lagging **Reactive Power** and **Minimum Generation** for 1 hour.

(d) operation of the **Synchronous Power Generating Module** at maximum leading **Reactive Power** and **Minimum Generation** for 1 hour.

(e) operation of the **Synchronous Power Generating Module** at maximum lagging **Reactive Power** and a power output between **Registered Capacity** and **Minimum Generation**.

(f) operation of the **Synchronous Power Generating Module** at maximum leading **Reactive Power** and a power output between **Registered Capacity** and **Minimum Generation**.

B.5.5.2 Where **Distribution Network** considerations restrict the **Synchronous Power Generating Module Reactive Power** output then the maximum leading and lagging capability will be demonstrated without breaching the **DNO** limits.

B.5.5.3 The test procedure, time and date will be agreed with the **DNO** and will be to the instruction of the **DNO** control centre and shall be monitored and recorded at both the **DNO** control centre and by the **Generator**.

B.5.5.4 Where the **Generator** is recording the voltage, **Active Power** and **Reactive Power** at the **Connection Point** the voltage, **Active Power** and **Reactive Power** at the **Synchronous Power Generating Module** terminals may also be included. The results shall be supplied in an electronic spreadsheet format. Where applicable the **Synchronous Power Generating Module** transformer tap changer position should be noted throughout the test period.

B.5.6 Governor and Load Controller Response Performance

B.5.6.1 The governor and load controller response performance will be tested by injecting

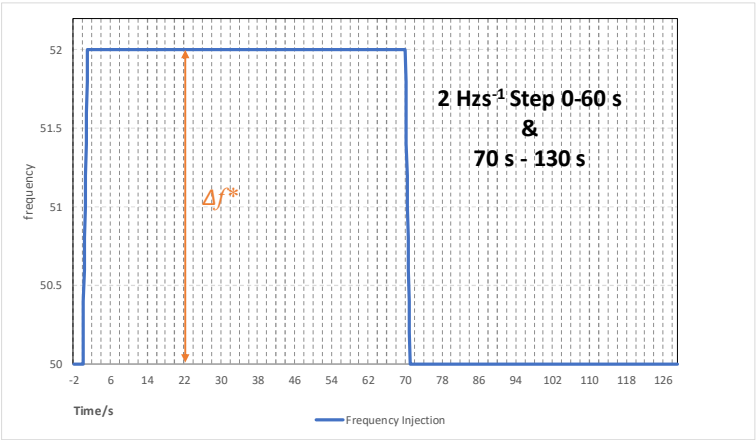
simulated frequency deviations into the governor and load controller systems.

B.5.6.2 The two frequency response tests in **Limited Frequency Sensitive Mode (LFSM)** to demonstrate **LFSM-O** capability to a frequency injection as shown by Figures B.5.1 and Figures B.5.2 are to be conducted at **Registered Capacity**.

B.5.6.3 There should be sufficient time allowed between tests for control systems to reach steady state. ~~Where the diagram states 'HOLD' t~~The injection signal should be maintained until the **Active Power** (MW) output of the **Synchronous Power Generating Module** or **CCGT Module** has stabilised. The **DNO** may require repeat tests should the tests give unexpected results.

B.5.6.4 The frequency input and the expected **Active Power** response which ~~is~~ are illustrated for different time periods from 0 to 130 s in Figures B.5.1 for a step change in frequency ~~-~~and B.5.2 for a ramp change in frequency. These should be in accordance with Section 12.2.4 and undamped oscillations should not occur after the step or ramp frequency change. Note for diagram purposes only a short interval is shown between the frequency increase and decrease for each test. In practice the return step or ramp can start any time after the output has stabilised after the first step or ramp.

B.5.6.5 The response should commence within 2 s ~~(or such time as the **DNO** might agree with the **Generator**); ie~~and the response ~~should normally~~must be to the left of the red line (ie between the green and red line), and as close to the green line as possible, when following the frequency step or ramp~~contained within the blue lines, and as close to the left as possible, when following the frequency ramp. The response should be complete in a reasonable time and the **DNO** can agree with the **Generator** a longer completion time than suggested by the blue lines taking into account the technical capabilities of the **Power Generating Module** and its prime mover~~. Note that the red line represents the 0.5%/s specified in 12.2.4.



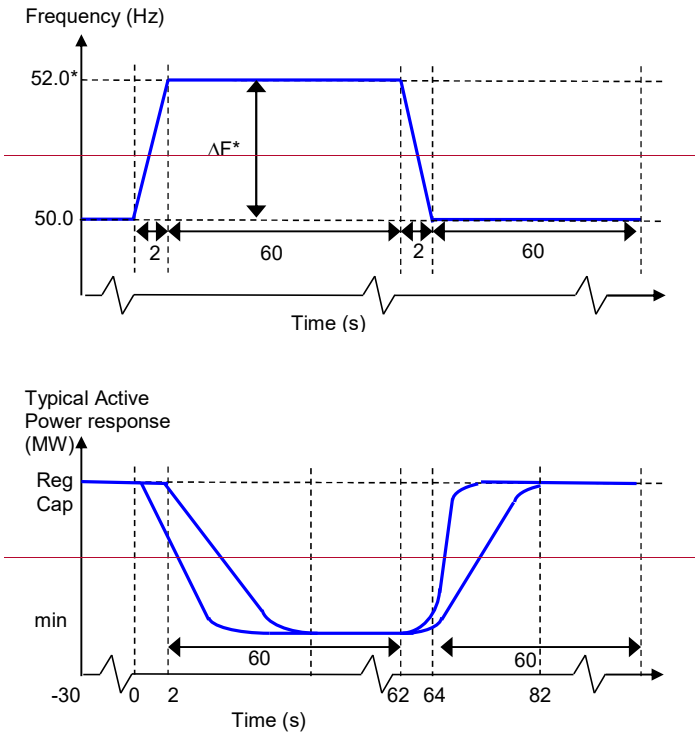


Figure B.5.1(i): LFSM-O step response test – frequency injection
Figure B.5.1(i): LFSM-O step response test – frequency injection

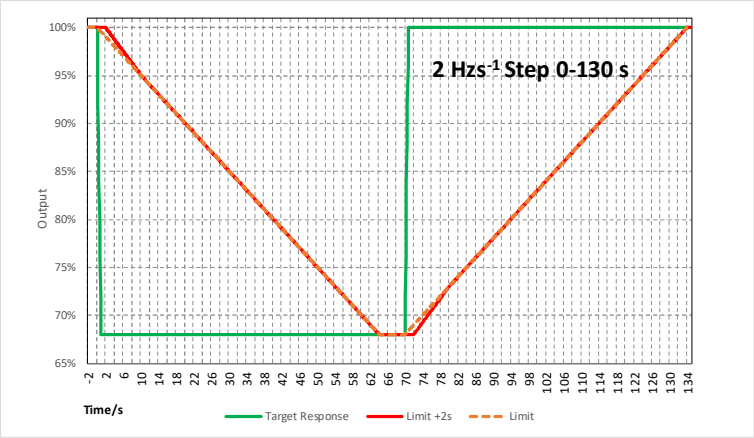


Figure B.5.1(ii): LFSM-O step response test – target response and limits
Figure B.5.1(ii): LFSM-O step response test – target response and limits

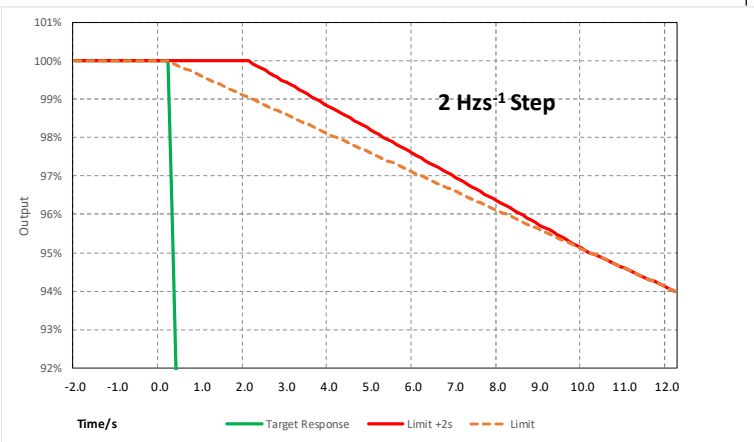


Figure B.5.1(iii): LFSM-O step response test – expansion of the allowed 2 s response delay (frequency increase)

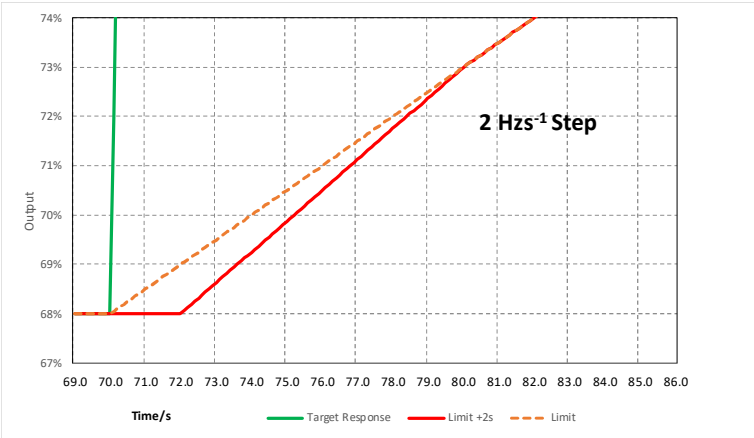


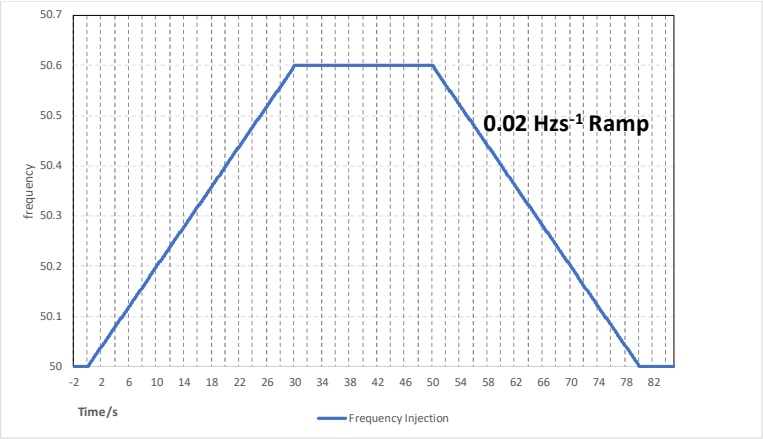
Figure B.5.1(iv): LFSM-O step response test – expansion of the allowed 2 s response delay (frequency decrease)

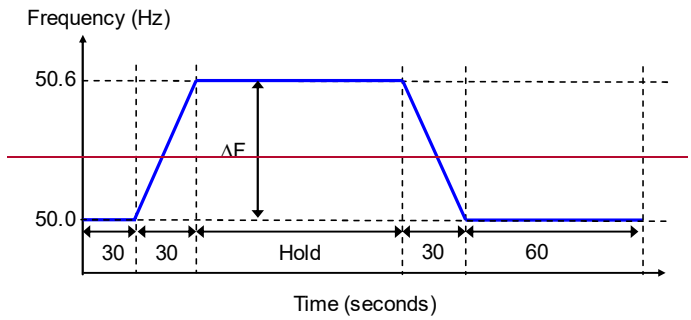
*The frequency step *Δf*~~* This~~ will generally be +2.0 Hz unless an injection of this size causes a reduction in plant output that takes the operating point below **Minimum Generation** in which case an appropriate injection should be calculated in accordance with the following:

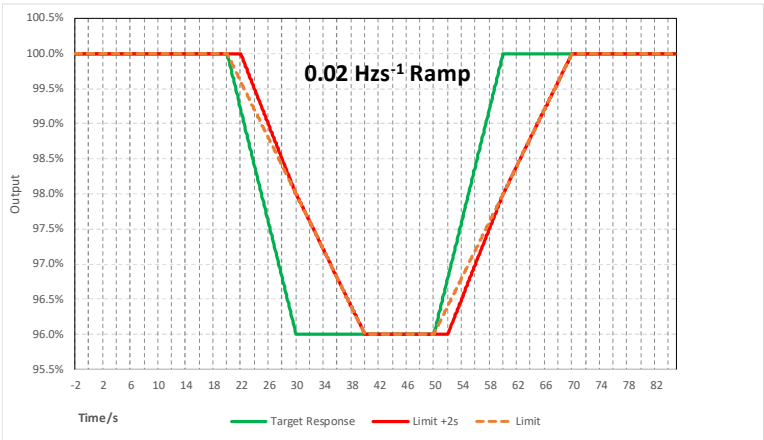
For example 1.5 Hz is needed to take an initial output 100% to a final output of 70%. If the initial output is not 100% and the **Minimum Generation** is not 70% then the injected step should be adjusted accordingly as shown in the example given below:

Initial output	100%

Minimum Generation	70%
Frequency controller **Droop**	10%
Frequency to be injected	= (1.00 – 0.70) x 0.1 x 50 = 1.5Hz







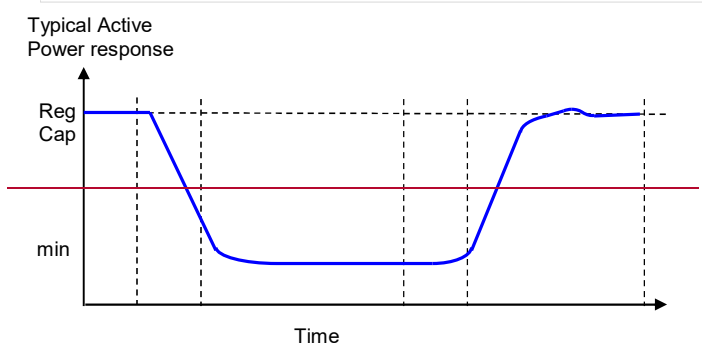


Figure B.5.2(i): LFSM-O ramp response test – frequency injection

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Figure B.5.2(ii): LFSM-O ramp response test – target response and limits

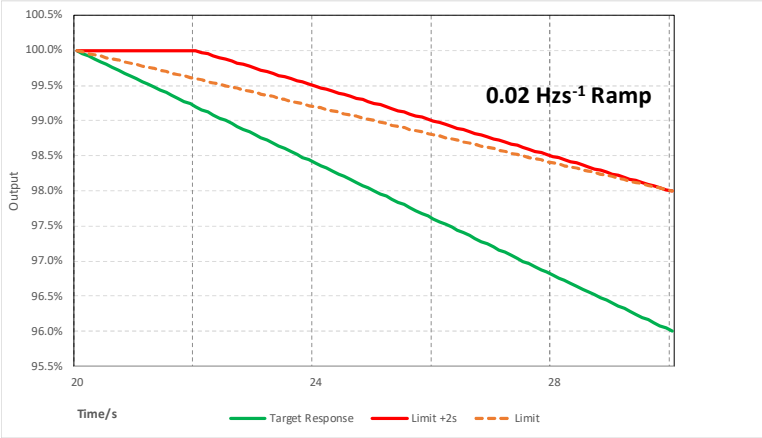

Figure B.5.2(iii): LFSM-O ramp response test – expansion (frequency increase)

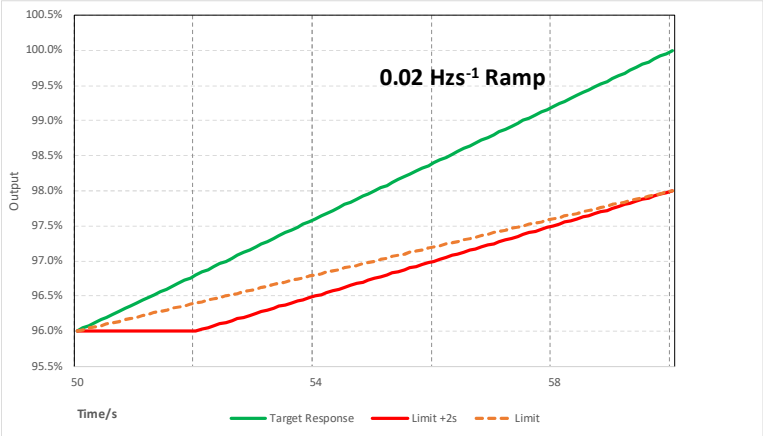

Figure B.5.2(iv): LFSM-O ramp response test – expansion (frequency decrease)

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B.5.7 Compliance with Output Power with falling frequency Functionality Test

B.5.7.1 The **Generator** will propose and agree a test procedure with the **DNO**, which will demonstrate how the **Synchronous Power Generating Module Active Power** output responds to changes in system frequency.

B.5.7.2 The tests can be undertaken by the **Synchronous Power Generating Module** powering a suitable load bank, or alternatively using the test set up of Figure A8.6. In both cases a suitable test could be to start the test at nominal frequency with the **Synchronous Power Generating Module** operating at 100% of its **Registered**

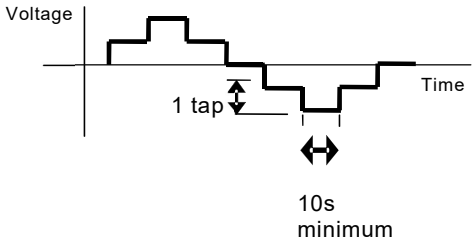


Figure B.6.1 – Transformer tap sequence for voltage control tests

(ii)

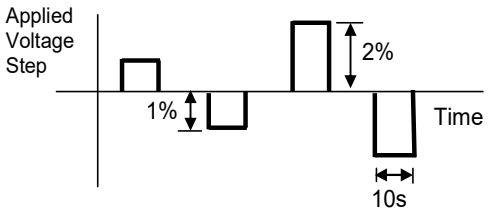


Figure B.6.2 – Step injection sequence for voltage control tests

B.6.5 Frequency Response Tests

B.6.5.1 This section describes the procedure for performing frequency response testing on a **Power Park Module**. These tests should be scheduled at a time where there are at least 95% of the **Generating Units** within the **Power Park Module** in service. There should be sufficient MW resource forecasted in order to generate at least 65% of **Registered Capacity** of the **Power Park Module**.

B.6.5.2 The frequency controller shall be in **Limited Frequency Sensitive Mode** for each test. Simulated frequency deviation signals shall be injected into the frequency controller setpoint/feedback summing junction.

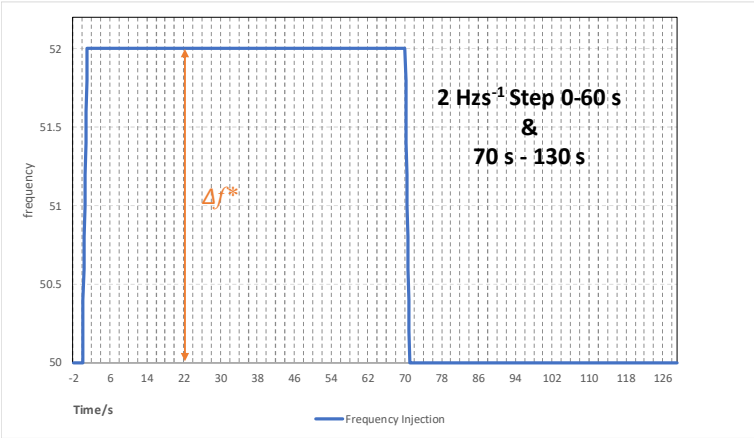
B.6.5.3 The two frequency response tests in **Limited Frequency Sensitive Mode (LFSM)** to demonstrate **LFSM-O** capability to a change in frequency as shown by Figure B.6.3 and B.6.4 are to be conducted at **Registered Capacity**.

B.6.5.4 There should be sufficient time allowed between tests for control systems to reach steady state (depending on available power resource). ~~Where the diagram states 'HOLD' t~~ The injection signal should be maintained until the **Active Power** (MW) output of the **Power Park Module** has stabilised. the **DNO** may require repeat tests should the response volume be affected by the available power, or if tests give unexpected results.

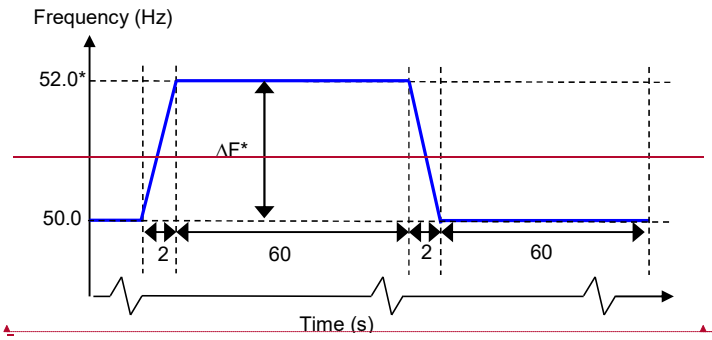
B.6.5.5 The frequency input and the expected **Active Power** response which are illustrated for different time periods from 0 to 130 s in Figures B.6.3 for a step change in frequency and Figures B.6.4 for a ramp change in frequency. This should be in accordance with Section 12.2.4 and undamped oscillations should not occur after

the step or ramp frequency change. Note for diagram purposes only a short interval is shown between the frequency increase and decrease for each test. In practice the return step or ramp can start any time after the output has stabilised after the first step or ramp.~~The expected **Active Power** response which is illustrated in Figure B.6.1 and B.6.2 should be in accordance with Section 12.2.4 and undamped oscillations should not occur after the step or ramp frequency change.~~

B.6.6.5 The response should commence within 2 s and the response must be to the left of the red line (ie between the green and red line), and as close to the green line as possible, when following the frequency step or ramp. Note that the red line



represents the 0.5%/s specified in 12.2.4.~~The response should commence within 2 s (or such time as the **DNO** might agree with the **Generator**) and complete in a reasonable time (typically no longer than 30 s); ie the response should be contained within the blue lines, and as close to the left as possible, when following the frequency ramp.~~



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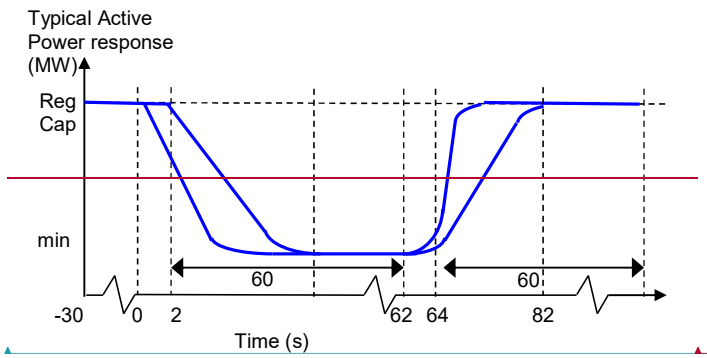

Figure B.6.3(i): LFSM-O step response test – frequency injection

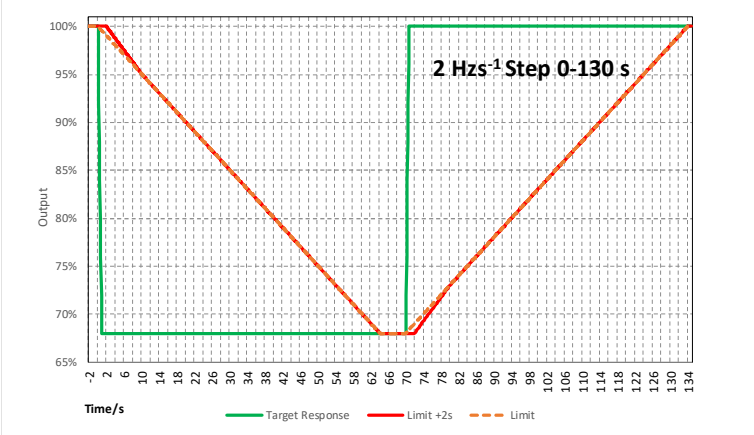

Figure B.6.3(ii): LFSM-O step response test – target response and limits

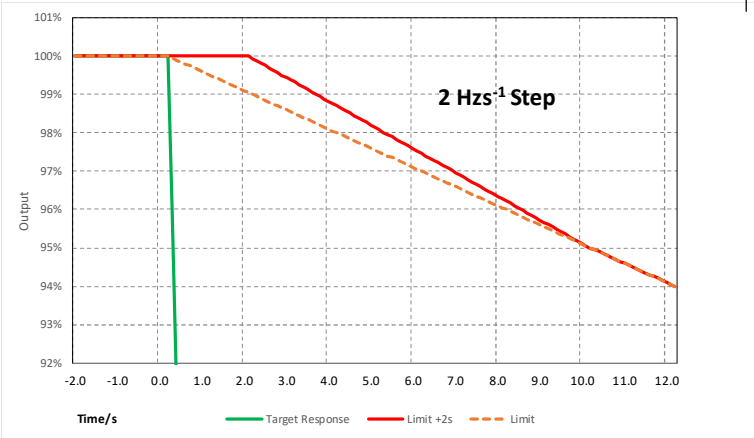

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Figure B.6.3(iii): LFSM-O step response test – expansion of the allowed 2 s response delay (frequency increase)

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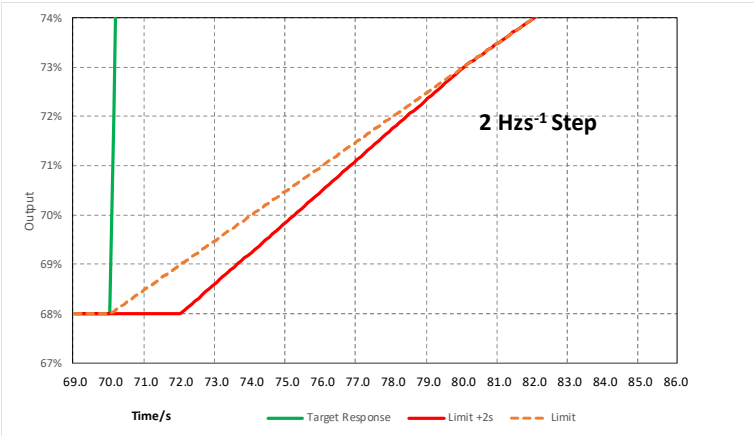


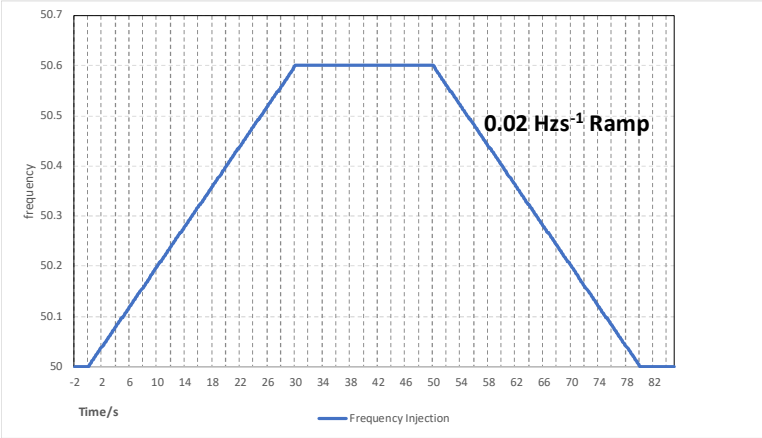
Figure B.6.3(iv): LFSM-O step response test – expansion of the allowed 2 s response delay (frequency decrease)

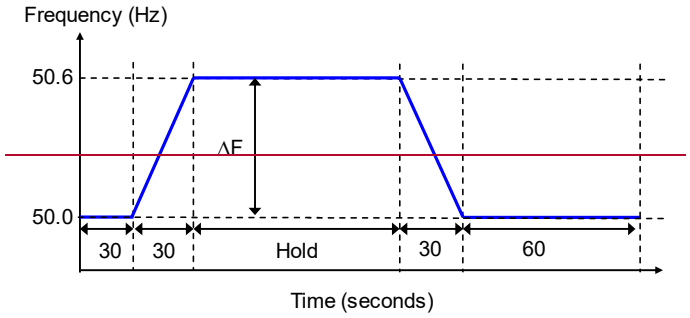
The frequency step Δf ~~This~~ will generally be +2.0 Hz unless an injection of this size causes a reduction in plant output that takes the operating point below **Minimum Generation** in which case an appropriate injection should

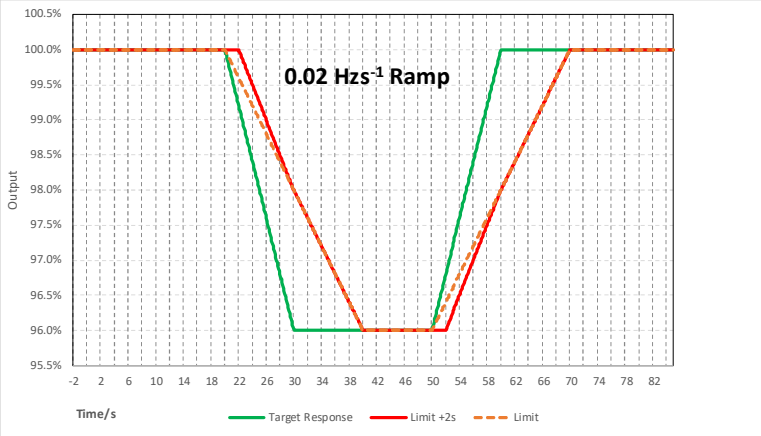
For example, 1.5 Hz is needed to take an initial output 100% to a final output of 70%. If the initial output is not 100% and the **Minimum Generation** is not 70% then the injected step should be adjusted accordingly as shown in the example given below:

Initial output	100%
Minimum Generation	70%
Frequency controller **Droop**	10%
Frequency to be injected	= (1.00 – 0.70) x 0.1 x 50 = 1.5Hz

Figure B.6.4: LFSM-O BC2 ramp response test


50.7
50.6
50.5
50.4
50.3
50.2
50.1
50
frequency
-2 2 6 10 14 18 22 26 30 34 38 42 46 50 54 58 62 66 70 74 78 82
Time/s
0.02 Hzs-1 Ramp
Frequency Injection


Frequency (Hz)
50.6
50.0
ΔF
30
30
Hold
30
60
Time (seconds)



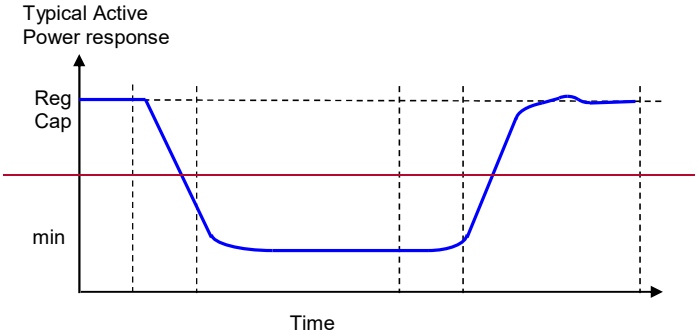
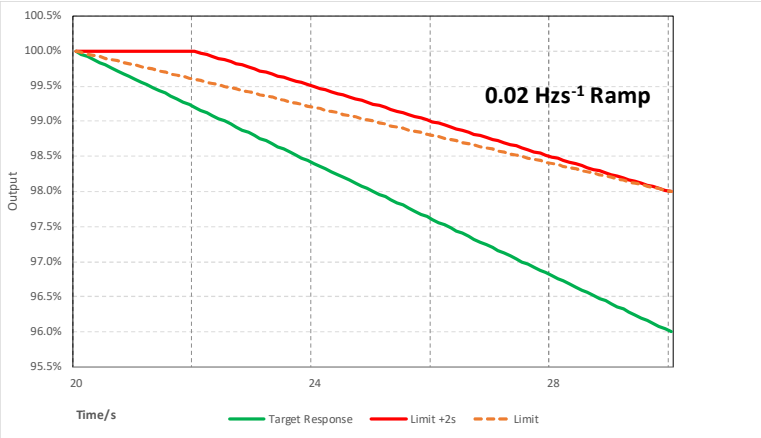


Figure B.6.4(ii): LFSM-O ramp response test – target response and limits



~~**Figure B.6.4: LFSM-O BC2 ramp response test**~~

Figure B.6.4(iii): LFSM-O ramp response test – expansion (frequency increase)

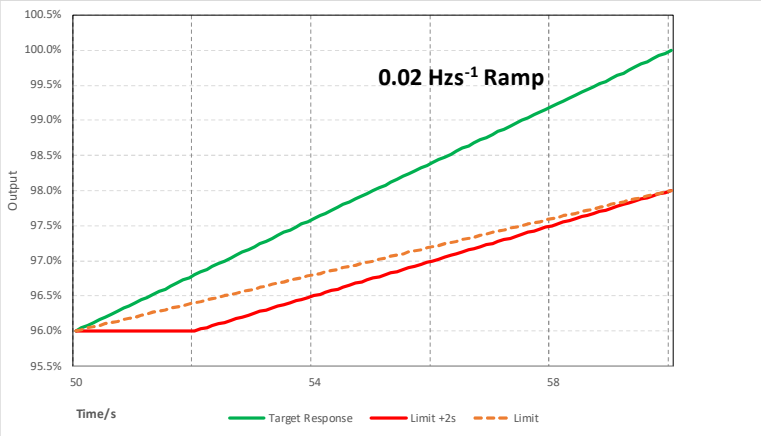


Figure B.6.4(iv): LFSM-O ramp response test – expansion (frequency decrease)