Please note that the webinar is expected to take 90 minutes.

Stability Pathfinder Technical Performance Criteria Webinar

14th August 2019

To allow everybody to sign in the webinar will start at 13:05

The audio for this webinar via telephone
+44(0)-20-7108-6317
Access code: 598 651 212

After the presentation we will be doing Q&A. Questions can be submitted any time via WebEx chat.

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Timescales for RFI

Technical RFI published	July 19th
Webinar	6th August
Technical Webinar (Today)	14th August
Feedback & Q&A updates	Regular
Deadline for RFI responses	13th September
RFI Feedback Publication	Mid October

Contents

Please submit any questions via WebEx chat.

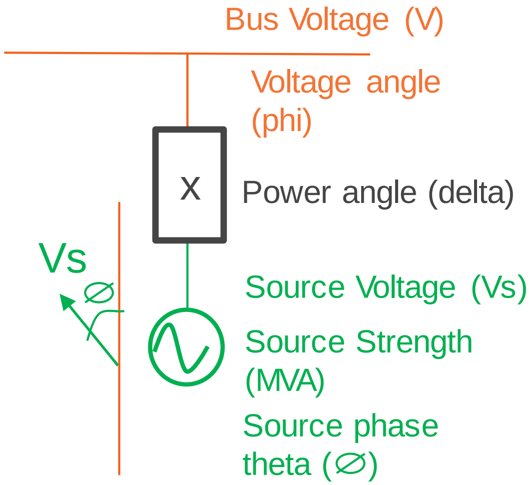
Minimum Technical Performance Criteria- General Points

- Each solution must be able to meet the minimum technical performance criteria specified in section 1.1 of RFI attachment 1.
- If the minimum capabilities are not met then the proposed solution cannot be further assessed.
- These minimum capabilities are expected to be demonstrated at the feasibility stage.
- If the minimum capabilities can be exceeded across all areas, the overall stability requirement can be met to a greater extent, this will be taken into account in the CBA.
- Other areas of additional performance may be taken into account as discussed in section 2 of the RFI.
- A solution is expected to meet all of the performance characteristics at all times it is available such that it performs across the range of disturbances that could occur- there are no trade-offs between performance areas in an event.
- Performance to be demonstrated at nearest onshore transmission connected node.
- Represents areas of performance additional to Grid Code minimum performance capabilities. The relevant other Grid code capabilities also need to be met.
- All requirements would need to be demonstrated, ahead of delivery of service.

Minimum Technical Performance Criteria- General points

What a Voltage source behind an impedance means

$$\text{Power supplied} = \frac{Vs*V*\sin(d)}{X} \quad \text{(where d= phi-theta)}$$

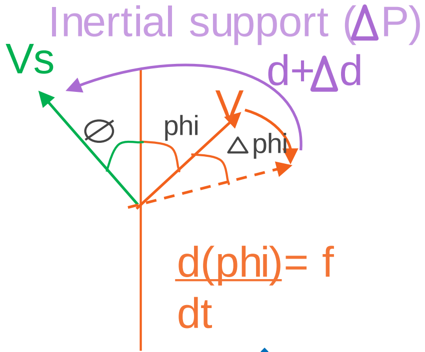


- A voltage source generates a given strength of injection (MVA) via a voltage phase (theta) which ensures the synchronised power has a power angle (delta) with the system suppling the active power in the steady state from the source to the system at the required magnitude.

- This is relative to the bus Voltage, and its angle (phi) as set by the broader voltage profile of the network at the time.

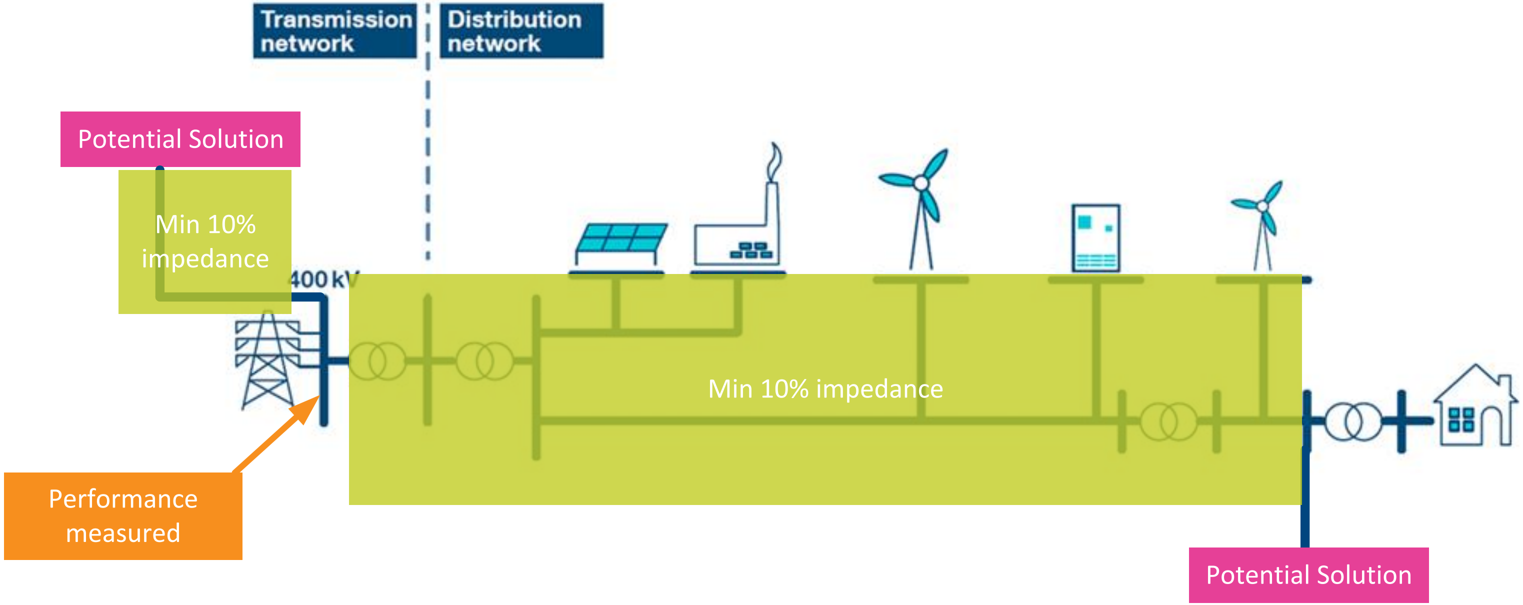
- In any disturbance of frequency, the angle of the bus Voltage (phi) will move – becoming more distant from the generator phase in a frequency depression. The rate of this change {d(phi)/dt} is the "frequency" that is measured, and also felt by the generator connected at that point.

- The Voltage Source holds its phase angle- this is what delivers inertial power. The inertia constant defines how that that angle then re-adjusts to a new relationship with the voltage angle. Higher inertia constant= higher level of inertia power supplied over time for the same disturbance.



Minimum Technical Performance Criteria- General points

How to demonstrate a Voltage source behind an impedance



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Specification areas potentially informing sizing of the solution

1.1.1.	Short Circuit Level
1.1.2.	Inertia
1.1.6	Transient voltage stabilisation and support capability
1.1.17	Repeatability of performance

1.1.1 Short circuit level

Short circuit level contribution (MVA) ≥ 1.5 p.u. of MVA available in steady state operation

During the fault and first 0.5s after the fault clearance, the delivery of rated reactive current injection (see section 1.1.9 for further information on the characteristic of this injection).

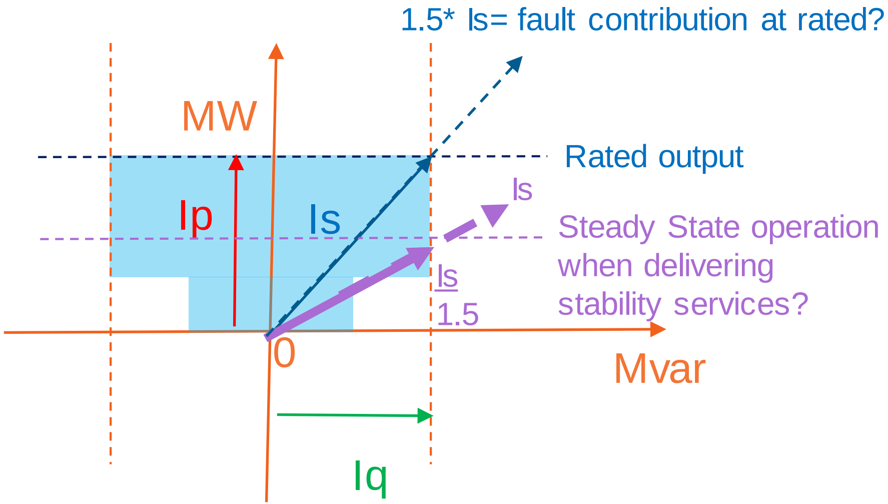
Example 1

Take a power park module connected at 400kV- Figure 1 performance chart.

$$\textbf{Short Circuit MVA} = \sqrt{3} * \textbf{Rated Voltage (kV)} * \textbf{Fault Current provided (kA)}$$

- At rated output of **500MW** (Ip=0.72kA), rated MVA= 526MVA (0.95pf) (Is=0.76kA. Mvar range =163Mvar. Iq= 0.24kA)
- To operate at 500MW and participate in stability support, an overload to a 789.5MVA (1.14kA) capability would be needed.
- *Or* a steady state operation at or lower than **310MW**, respecting a 164Mvar range could be selected, this would represent 351MVA (0.51kA), with a 1.5p.u. overload value of 526MVA (0.76kA) and may not require overload capability as such.

Figure 1



Ip = Active current
Iq = Reactive current
Is = Total current

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1.1.1 Short circuit level *(Continued)*

Please submit any questions via WebEx chat.

Iq = Reactive current

Is = Total current

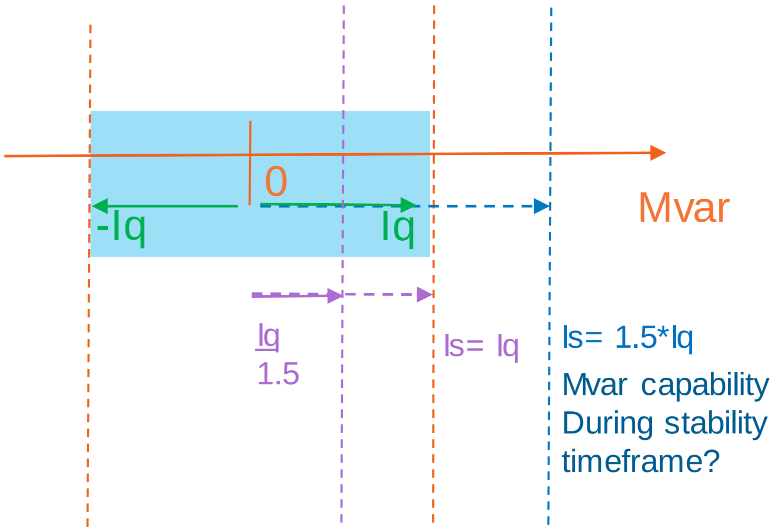
Example 2

Take a new solution with no rated (continuous) MW value.
connected at 400kV, 500Mvar capacity- Figure 2 performance chart.

$$\textbf{Short Circuit MVA} = \sqrt{3} * \textbf{Rated Voltage (kV)} * \textbf{Fault Current provided (kA)}$$

- At rated output of 500Mvar (Iq= 0.72kA), rated MVA= 500MVA
- To operate at 500Mvar and participate in stability support, an overload to a 750MVA (Is=1.08kA) capability would be needed.
- *Or* a steady state operation at or lower than **333Mvar**, 333MVA (0.48kA), such that the fault current would be delivered on a 500MVA (Is= 0.72kA) basis.

Figure 2



1.1.1 Short circuit level *(Continued)*

Example 3: Why is there a need for at least 1.5p.u. overload?

Figure 3a, taken from 2014 SOF shows an example, for illustration purposes of a fault condition.

Figure 3b shows the effect of the voltage source behind a minimum impedance of 10% on the MVA of normal operation close to the fault point.

Figure 3a

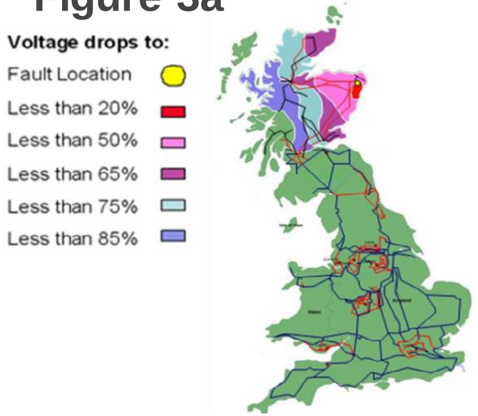


Figure 3b

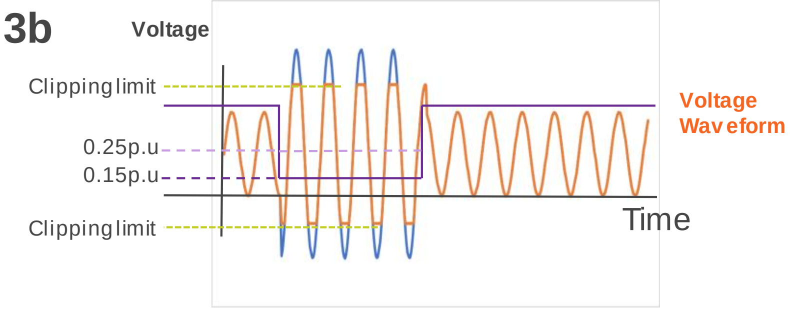
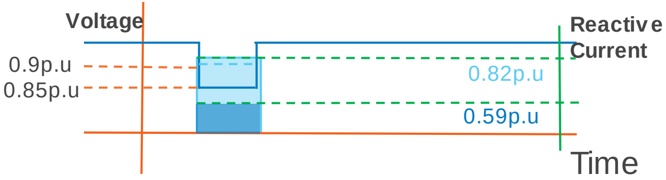


Figure 3c shows the response of the voltage source remote from the fault point.

- The 1p.u. injection near the fault provides the same magnitude of fault current, but introduces more noise if acceptably limited to avoid overload. However the level of per MW injection of fault current provided is 33% less, meaning other providers would need to be found.
- The 1p.u. injection away from the fault limits the Mvar support both on a per MW and absolute basis.

Figure 3c



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1.1.2 Inertia

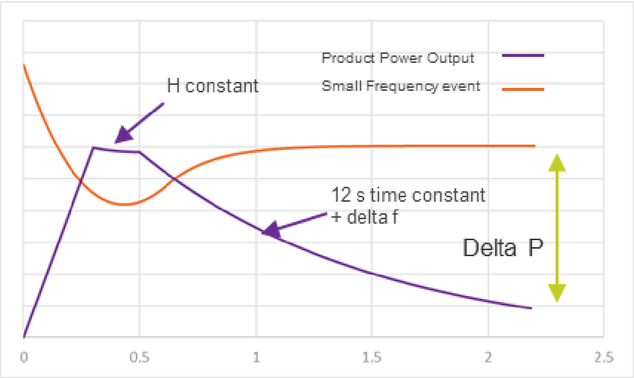
Solution is expected to respond inertially to the phase movement.

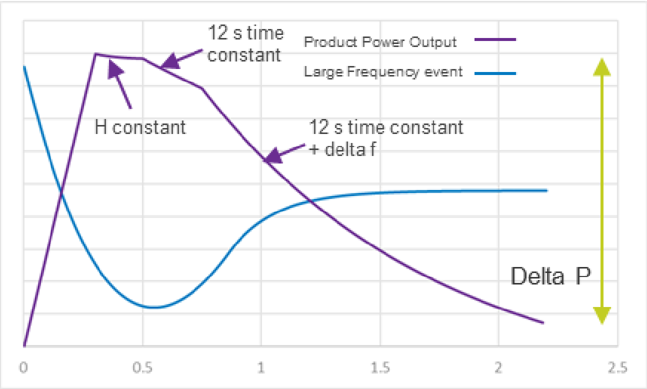
Inertia (MVA.s) ≥ 1.5 p.u. of MVA available in steady state operation

During the fault and first 0.5s after the fault clearance, the delivery of rated reactive current injection (see section 1.1.9 for further information on the characteristic of this injection) and any additional active power required to achieve the effect of this inertia constant must not degrade faster than the degradation corresponding to a 12s decay in capability.

Figures are illustrative

Swing equation relationship to determine additional active power to allow df/dt of upto 1 Hz/s

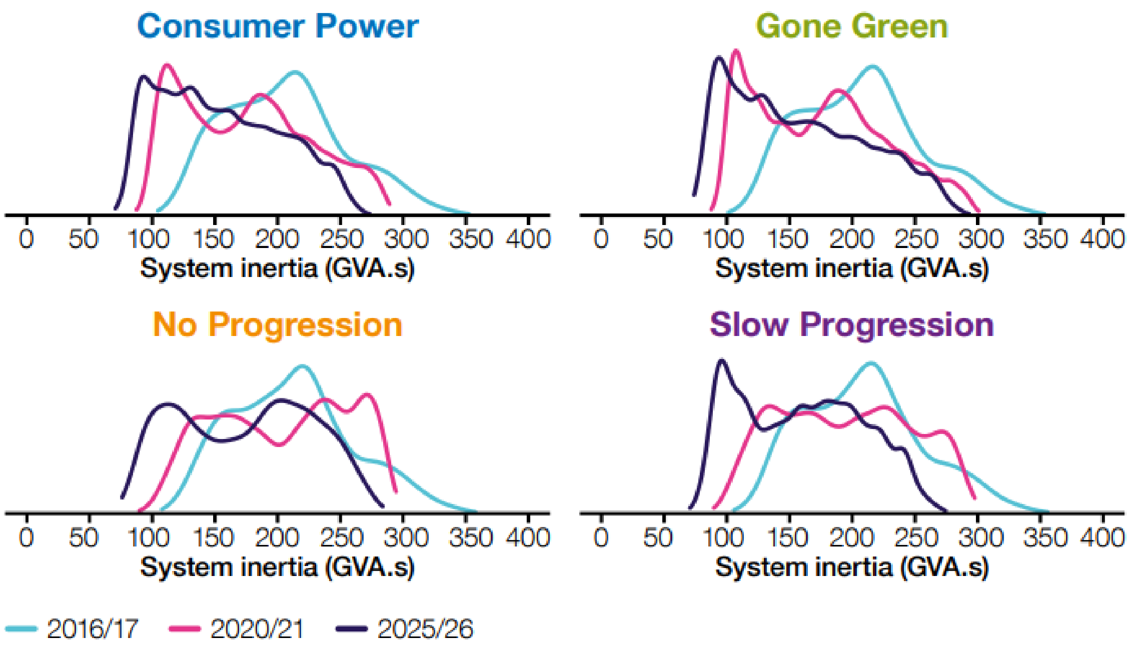




12 s time constant = 20s decay duration

1.1.2 Inertia *(Continued)*

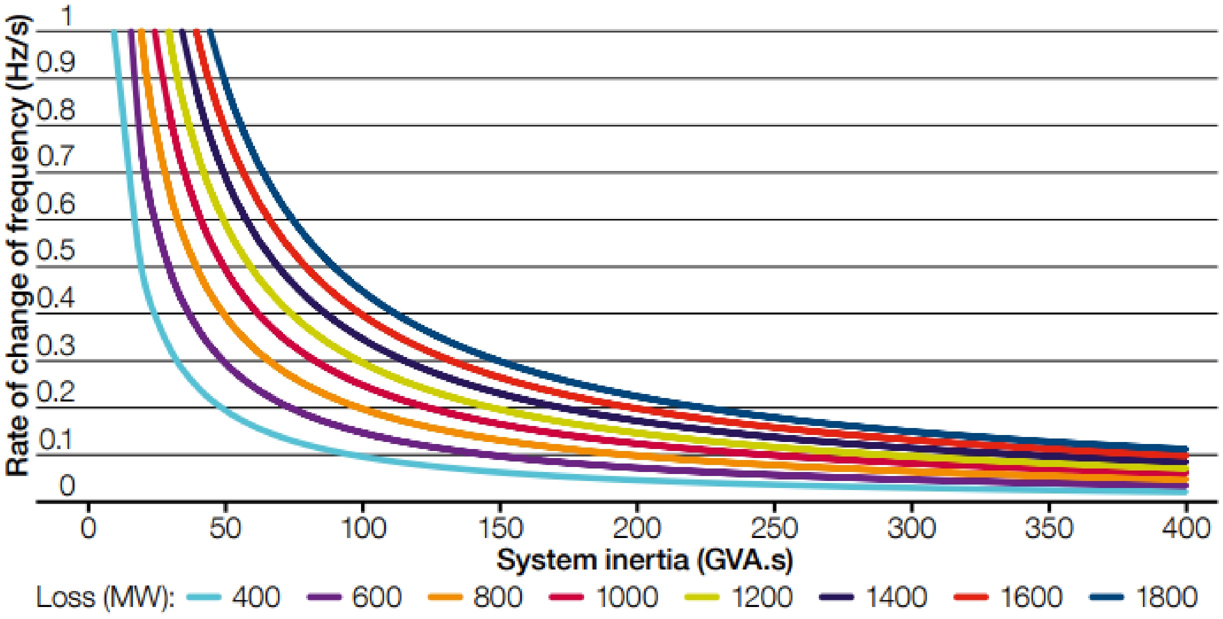
Figure 3.7
*Annual distributions of system inertia (GVA.s) by scenario (**flexibility case B**)*



Reference SOF 2016 document

1.1.2 Inertia *(Continued)*

Figure 3.11
Instantaneous absolute RoCoF, relationship between absolute loss size and inertia



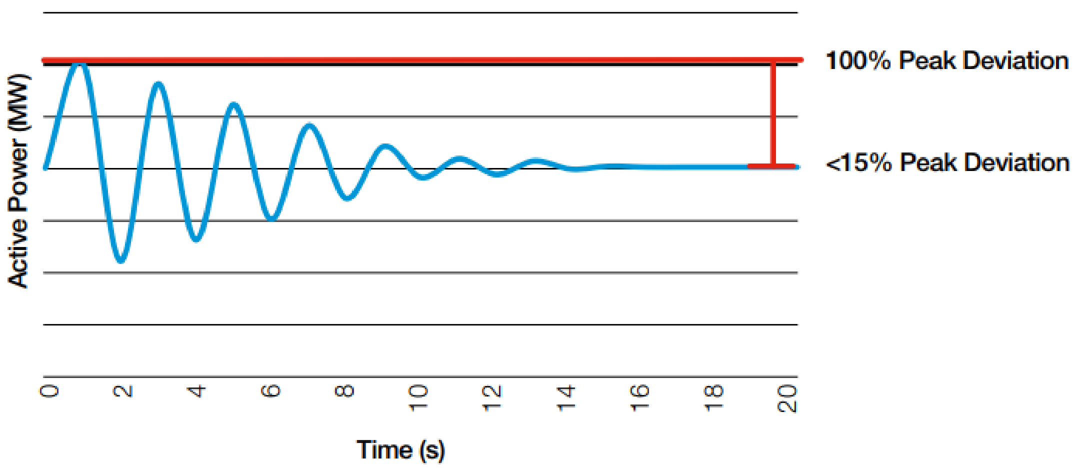
Reference SOF 2016 document

1.1.6 Transient voltage stabilisation and support capability

The solution is expected to continuously provide reactive current response with the connected voltage movement consistent with the performance of a voltage source behind an impedance.

After 100ms subject to further ESO connection point specification, the solution is expected to be capable of active and reactive **power oscillation damping**.

Figure 65
NETS SQSS Power Oscillation Damping Requirement



12 s time constant = 20s decay duration

https://www.nationalgrideso.com/document/63461/download

1.1.6 Transient voltage stabilisation and support capability

- Analogous to a synchronous machine, the solution is expected to provide continuous voltage support by reactive current injection (within the voltage against time curve referred in 1.1.5 fault ride through criteria).

  - The effect of this response has the potential to either damp or add to inter-area oscillation occurring across recovery period.
  - Dependent on the location, the device is expected to introduce a fast acting power oscillation damping control of nominated speed and frequencies of damping.
  - The speed where required may be <500ms for appreciable damping to be achieved and its setting and tuning will be the product of analysis at detailed design stage.

- Where the solution includes active power production prior to a voltage disturbance, the solution must ensure that the delivery of reactive current to stabilise the voltage disturbance is prioritised over active power recovery, to (at least an equivalent basis of response as would be delivered inherently by a voltage source behind a 10% or higher impedance to the point of common coupling) , whilst ensuring that active power recovery by 500ms is in linear relationship with recovered voltage (as provided for by Grid Code ECC 6.3.15).

  - The precise details of the power recovery will be discussed and agreed with the ESO at detailed design stage, such that the response does not unduly contribute to locally measured frequency and/or RoCoF across this period.

1.1.17 Repeatability of performance

- The provider is required to confirm their repeated ability to operate through voltage and frequency disturbances. This may, where appropriate, include the supplier providing details of the protection and/or control approach and further describing and agreeing where applicable an approach which avoids any limit in the repeated performance that could be achieved by the solution.

- In order to maintain availability and operation across multiple disturbances, as required, provider may alternatively:
  - limit subsequent performance in that subsequent disturbance and/or,
  - the pre-fault operation of the solution as necessary

- These aspects of control and performance would need to be detailed to the ESO and agreed between the ESO and supplier in the detailed design of the solution.

Fault statistics information can be found at:
https://www.nationalgrideso.com/codes/grid-code/modifications/gc0075-hybrid-static-compensators

Questions & Answers – 10 mins

Please submit any questions via WebEx chat.

- We will answer as many as we can in the time we have.
- We will publish written responses to all question submitted on our website as soon as we can.
- If your question contains confidential material mark it as such and tell us why is it confidential, and we will respond to you directly.

Send any additional questions to:
box.networkdevelopment.roadmap@nationalgrideso.com

Please submit any questions via WebEx chat.

Specification areas relating to and complementing codes obligations

1.1.3	Steady state voltage
1.1.4	Steady state frequency
1.1.10	Rate of change of frequency (RoCoF) withstand
1.1.5	Fault ride through
1.1.13	Voltage recovery at or better than defined in codes
1.1.7	Fast fault current injection
1.1.15	Voltage dependant droop control/auto switching
1.1.8	Transient angle change
1.1.9	Transient voltage angle movement
1.1.11	Temporary over voltage (TOV) withstand
1.1.12	Temporary over voltage (TOV) absorption
1.1.14	Performance across range of minimum short circuit levels
1.1.16	Flicker/voltage distortion
1.1.18	Provision of model
1.1.19	Minimum relevant code and standards' compliance as applicable across existing codes

10 mins Q&A after 1.1.15

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1.1.3 Steady state voltage

Solution is expected to withstand voltage changes following a network disturbance/fault

- +/- 10% within 15mins
- +5% / -10% continuous

1.1.4 Steady state frequency

Solution is expected to operate across the range 47Hz - 52Hz.

1.1.10 Rate of change of frequency (RoCoF) withstand

Solution is expected to be robust to any RoCoF

- occurring ≤ 1Hz/s on average or in absolute change across a sampled window of 500ms
- instantaneously measured exceeding this level within the sampled window period

1.1.5 Fault ride-through

Solution is expected to ride-through voltage depressions

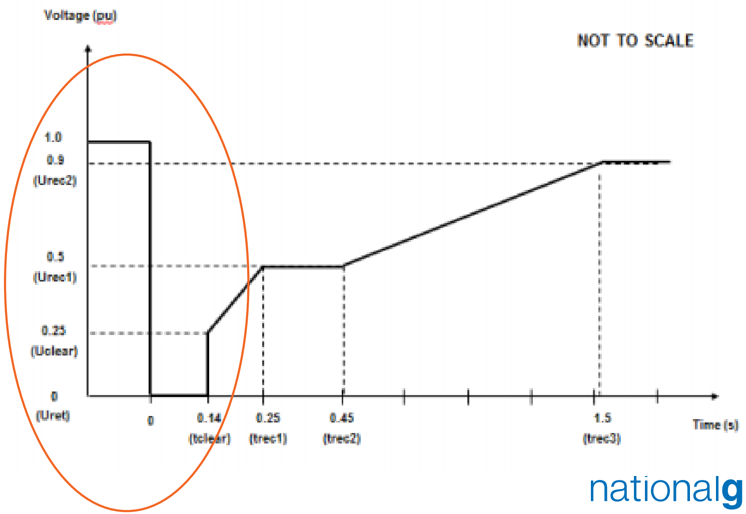
- 0-0.3p.u. within 140ms

across a family of voltage depression curves of longer duration as described in the Grid Code.

Grid Code section ECC.6.3.15 defines fault ride through conditions for different plant types. We are defining 0-0.3p.u within 140ms criteria for all potential solutions.

Example Voltage against time curve from Grid Code ECC.6.3.15

ECC.6.3.15.4 Voltage against time curve and parameters applicable to **Type D Synchronous Power Generating Modules** connected at or above 110kV



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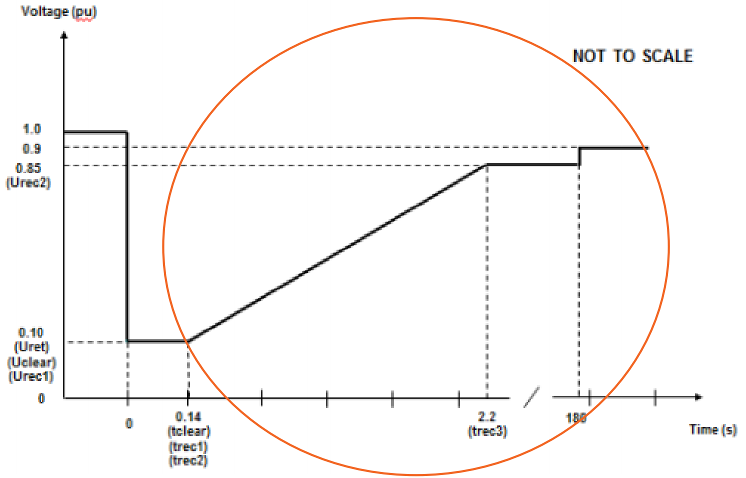
1.1.13 Voltage recovery at or better than defined in codes

Solution, dependent on voltage level of connection and scale, is expected to remain connected across the appropriate voltage against time recovery after fault clearance.

ECC.6.3.15.5 Voltage against time curve and parameters applicable to **Type B, C** and **D Power Park Modules** connected below 110kV

Grid Code section ECC.6.3.15 defines fault ride through conditions for different plant types.

Example voltage against time curve from Grid code ECC6.3.15



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1.1.7 Fast fault current injection

Solution is expected to

- provide reactive current injection into a retained voltage depression at point of connection, within 5ms of event

Grid Code section ECC.6.3.16 defines fast fault current injection conditions for different plant types. We are defining fast fault current injection to initiate within 5ms which goes beyond minimum grid code requirements.

1.1.15 Voltage dependant droop control/auto switching

Solution is expected to deliver a droop response of 4% or better.

Questions & Answers 10 mins

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1.1.8 Transient angle change

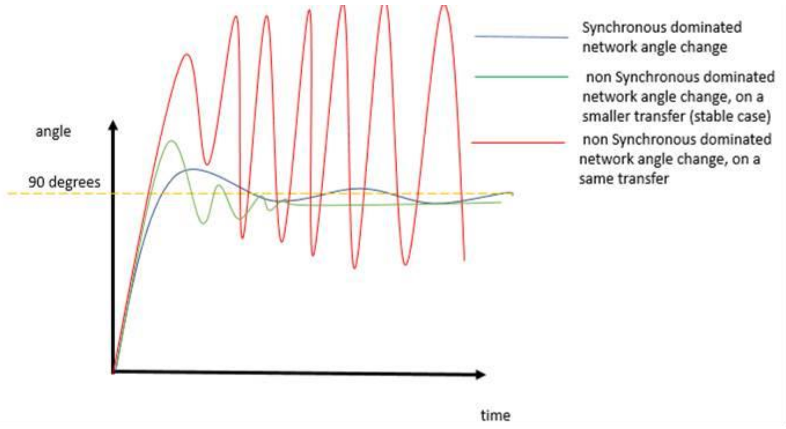
Diagrams are illustrative

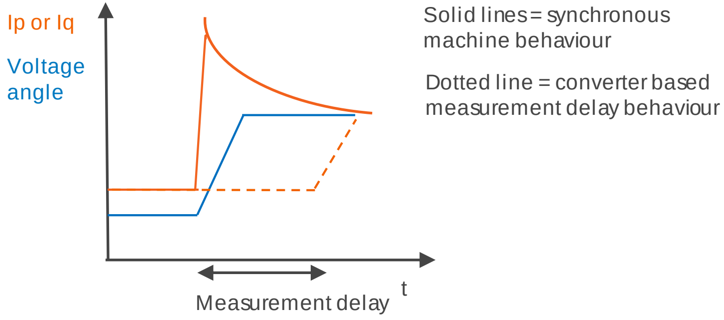
During the fault and for the first 0.5s after fault clearance, the solution is expected to respond up to its rating with reactive current countering the initial voltage angle change.

Following a fault clearance, solution is expected to ride-through voltage angle deviations of

- at least 90 degrees as measured within 60ms
- up to 200 degrees as occurring within 5ms
- angle change up to 200 degrees across a period of up to 0.5s. Thereafter, ride-through any event greater than 90 degrees in scale

This voltage angle change may occur at the time of fault, the point of fault clearance or at any time up to 300ms following fault clearance.





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1.1.9 Transient voltage angle movement

- During any voltage or frequency disturbance, solution is expected to maintain its phase of reactive and, as relevant active power and current injection over a period of no shorter than 0.5s after fault/disturbance.

- The phase injection of current must be delivered consistent with being modelled as the effect of a voltage source behind an impedance of no less than 10% on machine base impedance. This will ensure that in response to the voltage angle movement in a fault, as power supplied becomes more inductive (or in a frequency event where a deficit in power causes the voltage angle to move faster/ slower), the device is actively resisting that phase change across the event. This is expected to include supplying reactive and where applicable active current supporting both voltage and frequency recovery.

- The solution is not required to provide support against voltage angle beyond 0.5s after fault clearance, but is expected to provide details of its performance beyond that point.

1.1.11 Temporary Over Voltage (TOV) withstand

Solution is expected to withstand an initial RMS overvoltage

- of up to 1.4p.u. (starting voltage dependent) for 100ms followed by a reduction in overvoltage towards no more than 1.05p.u. as per the requirements of TGN(E) 288

The rms value is calculated in accordance with Class A requirement specified in IEC 61000-4-30 for voltage dips and swells, which states that rms is calculated over one complete cycle refreshed every half a cycle.

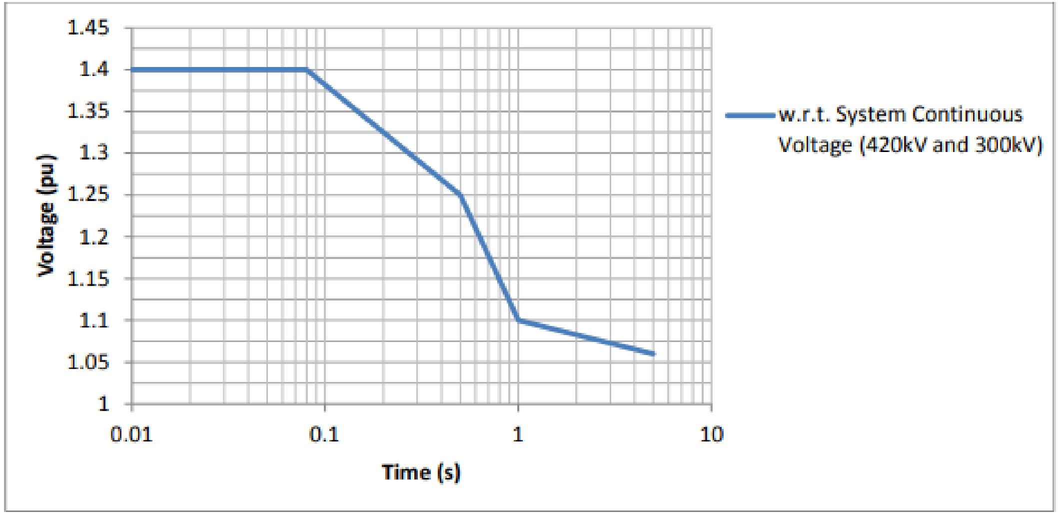


Fig 1- Limits for RMS Value of TOVs for 400kV and 275 kV in GB Network

1.1.12 Temporary Over Voltage (TOV) absorption

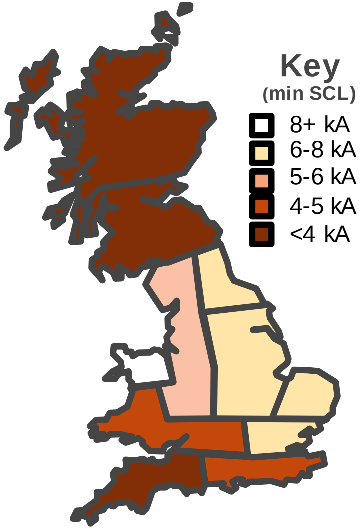
- During the overvoltage condition defined in 1.1.11, the solution is expected to respond near instantaneously such that within 5ms an appreciable level of reactive current absorption can be delivered (see section 1.1.9 for further information on the characteristic of this injection).

- The precise level provided being determined in comparison with the performance of a voltage source behind an impedance of no less than 10% on rating between the transmission system connection point and the source, up to at least 1p.u. response against solution's steady state reactive current.

- Where the solution provides active power prior to a voltage disturbance, the device is expected to ensure that the delivery of **reactive current to stabilise the voltage disturbance is prioritised over its active power recovery** (*at least an equivalent basis of response as would be delivered inherently by a voltage source behind a 10% or higher impedance to the point of common coupling- see section 1.1.9*), whilst ensuring that active power recovery is by 500ms is in linear relationship with recovered voltage (as provided for by Grid code ECC6.3.15).

1.1.14 Performance across range of minimum short circuit levels

Solution is expected to be robust to operate across a range of minimum short circuit levels expected to be within range of 3-13kA. Refer to Appendix B for GB area specific information.



Minimum SCL range 3 -13.5 kA

- We refer to short circuit ratio (SCR) in section 2.2 of Attachment 1.
- **By SCR, we mean being the ratio between the network strength and size of solution in MVA.**

$$SCR = \frac{\textit{Short circuit level in MVA at transmission node}}{\textit{Size of solution in MVA}}$$

- SCR not higher than 0.96 is meant to represent that the short circuit strength of the network may not be higher than 0.96*the size of the connecting device (without the contribution of the device being taken into account).
  - It is not meant to include reference to synchronous machine design.

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1.1.16 Flicker/voltage distortion

Solution, when switched, is expected to stay within established flicker limits, based on the minimum short circuit levels defined in 1.1.14. (Refer to Grid code CC.6.1.7, ER P28)

Supply system Nominal voltage	**Planning level**	
	Flicker Severity Short Term (Pst)	**Flicker Severity Long Term (Plt)**
3.3 kV, 6.6 kV, 11 kV, 20 kV, 33 kV	0.9	0.7
66 kV, 110 kV, 132 kV, 150 kV, 200 kV, 220 kV, 275 kV, 400 kV	0.8	0.6
NOTE 1: The magnitude of P_{st} is linear with respect to the magnitude of the voltage changes giving rise to it. NOTE 2: Extreme caution is advised in allowing any excursions of P_{st} and P_{lt} above the planning level.		

Table CC.6.7.1(b) — Planning levels for flicker

The values and figures referred to in this paragraph CC.6.1.7 are derived from Engineering Recommendation P28 Issue 2.

1.1.18 Provision of model

The model should describe the behaviour of solution. An appropriate RMS power system model will be required. Where non-synchronous in nature, further EMT model demonstration shall also be required.

1.1.19 Minimum relevant code and standards' compliance as applicable across existing codes

Where otherwise not specified, the solution is expected to meet relevant Grid Code obligations of synchronous and/or non-synchronous providers.

1.1.20 Availability

Solution is expected to remain available for 90% of a year. Planned closures and outages are expected to be agreed with the ESO.

We want to understand your views on being available at all :

- Available and delivering stability for 90% of the year
- Available to be instructed for 90% of the year; delivering stability on instruction at few hours' notice

Questions & Answers for remaining time

Please submit any questions via WebEx chat.

- We will answer as many as we can in the time we have.
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