Workgroup Consultation Response Proforma

GC0137: Minimum Specification Required for Provision of GB Grid Forming (GBGF) Capability (formerly Virtual Synchronous Machine/VSM Capability)

Industry parties are invited to respond to this consultation expressing their views and supplying the rationale for those views, particularly in respect of any specific questions detailed below.

Please send your responses to grid.code@nationalgrideso.com by 5pm on **30 April 2021**. Please note that any responses received after the deadline or sent to a different email address may not receive due consideration by the Workgroup.

If you have any queries on the content of this consultation, please contact Kavita Patel Kavita.patel@nationalgrideso.com or grid.code@nationalgrideso.com

Respondent details	Please enter your details
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For reference the Applicable Grid Code Objectives are:

a) *To permit the development, maintenance and operation of an efficient, coordinated and economical system for the transmission of electricity*
b) *Facilitating effective competition in the generation and supply of electricity (and without limiting the foregoing, to facilitate the national electricity transmission system being made available to persons authorised to supply or generate electricity on terms which neither prevent nor restrict competition in the supply or generation of electricity);*
c) *Subject to sub-paragraphs (i) and (ii), to promote the security and efficiency of the electricity generation, transmission and distribution systems in the national electricity transmission system operator area taken as a whole;*
d) *To efficiently discharge the obligations imposed upon the licensee by this license and to comply with the Electricity Regulation and any relevant legally binding decisions of the European Commission and/or the Agency; and*
e) *To promote efficiency in the implementation and administration of the Grid Code arrangements*

Please express your views regarding the Workgroup Consultation in the right-hand side of the table below, including your rationale.

Standard Workgroup Consultation questions		
1	Do you believe that the GC0141 Original	There are improvements, but EMT models mentioned in GC0141 are part on international

	Proposal better facilitates the Applicable Objectives?	best practice for IBR modelling and are highly desirable. See later comments.
2	Do you support the proposed implementation approach?	Yes.
3	Do you have any other comments?	See more detailed comments at the end of this document.
4	Do you wish to raise a Workgroup Consultation Alternative Request for the Workgroup to consider?	No. I am happy to provide the informal comments at the end of this document. I hope some may be of interest to the workgroup.
Modification Specific Workgroup Consultation questions		
5	Do you believe it is appropriate specify GB Grid Forming as a non-mandatory requirement in the Grid Code and be accessed by future market arrangements rather than as a mandatory requirement?	I would suspect that making it mandatory, with a reasonable long introduction period, may give the lowest system operating costs and highest grid resilience.
6	Do you believe the current proposal is sufficiently flexible and facilitates a range of technologies? If not, please state why you feel this to be the case and what type of technologies have been excluded?	The proposal allows a good degree of flexibility, but the current proposal makes no mention of the use of smart loads as a mechanism to address grid stability issues. This should be considered as part of the overall system analysis. See latter comments
7	Do you believe the proposal will result in excessive equipment costs? This excludes development costs whilst recognising plant can be also be de-loaded?	No. The proposal is a good compromise between improved performance and minimal hardware costs.
8	Do you believe the proposed Grid Code proposals sit better in the Planning Code, Connection Conditions / European Connection Conditions and Compliance Processes / European Compliance Processes bearing in	No comment

	mind the proposals are non-mandatory or do you think it would be better to have a new standalone section	

Comments and observations

I would like to congratulate the team involved in the production of the consultation documents. This appears to be world leading activity in a very important area.

I offer the follow comments on the consultation document and one annex.

Frequency response

page 23
Introducing requirements for bode plots is a good step forward to adopting some of the tools from a control systems approach to stability analysis.
"To supply relevant data (Network Frequency Perturbation Plot and Nicolls Charts or equivalent) so that the ESO can verify that the plant will not have any negative interactions with the Transmission System or other User's Plant and ensure an adequate level of damping. "

Ideally plots and modelling capability should consider the frequency range up to 1 kHz. This is so that it includes performance at low harmonic frequencies and allow analysis at the 5ms response time specified for step change response.

It should be noted that direct measurement of inverter based resource frequency response is possible. For example, see the work of Lingling Fan for example
https://naspi.org/sites/default/files/2021-04/D1S3_01_fan_usf_naspi_20210413.pdf

Should UK grid research and test community consider a similar facility in UK? This would allow independent verification on manufacturers measurement and simulation models. It should be noted that a high-power inverter-based plant is often made up of many lower power inverters. Testing individual inverters can make a valuable contribution.

Terminology

Page 20 "The "outer" control loops do not include the "inner" parts of a GBGF-I's control system which emulate the inertia and damping functions provided by a real Synchronous Generating Unit. "

Would it be better to specify required performance in terms of gain and phase margin, rather than basing around the derived term damping factor? These parameters are likely to be directly available from simulation and measurement.

As we move towards 100% inverter-based grids it would be good to drop historic terms, such as torque (mentioned in multiple places in the document), and replace with terms which are more applicable to modern IBR grids. Similarly, the term inertia is often mis used. Most IBR resources, operating below 100% capacity, can provide fast acting power reserve, without the need for the typical inertial recovery period. This should be used as a benefit not forcing IBR to emulate inertia and not using the term inertia.

Load and demand side response

Page 37 fig 14
The impact of the changing nature of load should be considered as part of grid stability. The reduction in synchronous load and increase in constant power loads will have a significant impact. Converter technology in loads and power factor correction make them look nicely resistive at line frequency, but the impedance changes rapidly in the region below 10Hz to with many loads becoming constant power for low frequency variation. To the best of my knowledge the effect on grid small signal stability has not been considered in any depth.

Grid following inverters have a bad reputation due to PLL unlocking. It is important not to blame the concept of a PLL. The issues relate to implementation. Grid forming inverters will include PLL functionality to allow tracking of grid phase.

Inverter based resources in most renewable generation cannot provide any sustained reserve power, unless their output is deliberately curtailed most of the time. This is not economically or environmentally efficient. Greater use of fast demand side response services could provide an alternative grid stability service in case of unplanned loss of generation.

Source impedance

Page 21 “The impedance would be real being made up of either one or a string of real impedances between the internal voltage source and connection point and would not comprise virtual impedances. “

This implies that the inverter has zero source impedance, without specifying a frequency range. Zero is unrealistic, should the limit be the virtual component is 10% max and over a defined frequency range?

Testing

Page 29 “The resolutions required to record these events are small. For a Grid Forming Converter with a fundamental frequency of 50Hz, a complete cycle takes place in 20ms which is equivalent to 2π radians or 360 degrees. Therefore a 5 degree change would take place in a timeframe of (5/360) x 20ms = 270μs and a 1 degree change would take place in 54μs. Therefore to accurately record these sorts of phase shifts a sampling time of 1μs (1MHz) is likely to be required.”

A phase change could be near “instantaneous” with appropriate voltage steps on the phases. In a 3-phase system phase can be measured instantaneously from the 3 phase voltages. The requirement for measurement could be based on the highest frequency component specified in the specification. I believe this is comes from the response time specified in document is 5ms.

"Dynamic System Monitoring Specification TS.3.24.70_RES" Specifies a sampling rate of 12.8 kHz and allowing for anti-aliasing this should provide accurate phase information at a rate of several k sample per second. This is likely to be ample to verify performance against the specification.

Simulation and Modelling

Page 27 and 28

"purpose is to assess the correct supply of "ROCOF Response Power" without going into saturation and that pole slipping does not occur."

It is important to consider the performance of the plant well outside the linear region. This should specifically look for large undesired response characteristics similar to pole slipping in a synchronous machine or PLL unlock in a grid following inverter.

This should include a clearly define list of fault conditions such as
Open circuit phase
Phase to GND short
Phase to phase short
Fault ride through
Harmonic
Voltage step

page 35

It is great that the document highlights the need to learn from international experience. I contribute to https://www.nerc.com/comm/PC/Pages/Inverter-Based-Resource-Performance-Task-Force.aspx

Regarding the approaches to modelling I would highlight the following document.
https://www.nerc.com/comm/RSTC_Reliability_Guidelines/Reliability_Guideline_BESS_Hybrid_Performance_Modeling_Studies_.pdf

This address many techniques that can be used to improve the modelling of complex inverter-based resources. This has particular emphasis on the use of EMT modelling and the accuracy of modelling, not just from frequency response, but also for fault cases which are not handled well by positive sequence phasor simulations.

PLL and response to phase change

Annex 9 Page 6
“Converters that use the Phase Locked Loop technology to keep their generated power constant when changes occur in the phase angle of the AC grid. This technology stops them producing the 3 Types of Phase based power.”
A PLL does not stop an IBR producing a damping effect. Choice of PLL control loop bandwidth is critical. Don’t blame the PLL, even grid forming inverters will include a form of PLL.

Annex 9 Page 5

The distinction between type 1, 2 and 3 could be clearer. My preference would be along the lines:-
Type 1 Step change in phase
Type 2 Linearly changing frequency (or RoCoF) (Using the term inertia can be confusing as it defines the response not the cause)
Type 3 Oscillating change in phase, at a frequency less than line frequency
Type 4 Control based is a confusing term, because in in an IBR all these powers are controlled.

Why is linear changing in phase (fixed frequency offset) is not mentioned as part of this analysis? Is it assume droop performance is unchanged?

Note that type 1, 2 and 3 powers identified above may be limited in the case where frequency is already low. For example available type 2 RoCoF power for a IBR will be less at 49.5Hz than it would be at 50Hz, because the IBR will already have increased its power due to droop settings and be closer to its current limit. In comparison inertia power for a synchronous machine is largely unchanged by frequency due to the temporary overload capability.