ESO

Final Self-Governance Modification Report

GC0163: GB Grid Forming (GBGF) - Removal of Virtual Impedance restriction

Overview: The purpose of this modification is to clarify the Grid Code with regard to the treatment of Virtual Impedance as defined within a Grid Forming Plant.

Modification process & timetable

1. **Proposal Form**
   22 October 2022
2. **Workgroup Consultation**
   22 January 2024 - 12 February 2024
3. **Workgroup Report**
   13 March 2024
4. **Code Administrator Consultation**
   02 April 2024 - 02 May 2024
5. **Draft SG Modification Report**
   22 May 2024
6. **Final SG Modification Report**
   10 June 2024
7. **Implementation**
   05 July 2024

Have 10 minutes? Read our Executive summary

Have 30 minutes? Read the full Final SG Modification Report

Have 60 minutes? Read the full Final SG Modification Report and Annexes.

Status summary: The Panel has made their determination vote, and an appeals window has opened.

Panel determination: The Panel has determined unanimously that the Proposer's solution is implemented.

This modification is expected to have a: Low impact on Generators, Manufacturers, Interconnectors

Modification drivers: New Technologies, System Security, Net Zero

Governance route	Self-Governance modification with assessment by a Workgroup.	
Who can I talk to about the change?	**Proposer:** Ronak Rabbani, ESO Ronak.rabbani@nationalgrideso.com	**Code Administrator Chair**: Elana Byrne elana.byrne@nationalgrideso.com
Appeals window	If you want to appeal this decision, please send your appeals form and relevant documentary evidence to industrycodes@ofgem.gov.uk by 5pm on 28 June 2024 and ensure you copy in grid.code@nationalgrideso.com	

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Executive summary

This modification proposes minor changes to the European Connection Conditions (ECC) and the Glossary & Definitions within the Grid Code to provide flexibility to developers as to how the impedance between the internal voltage source and Grid Entry Point or User System Entry Point (if Embedded) is provided. The current Grid Code only permits this to be achieved by a real impedance. Following publication of the GB Grid Forming Best Practice Guide in April 2023, it was agreed that with the necessary compliance processes in place, this requirement could be relaxed, permitting developers to provide this impedance either virtually (i.e., through software), or retaining the use of real physical components or a combination of the two. In practice, it is envisaged that developers will in the main use a combination of virtual and real impedances which will result in greater flexibility and cost savings. The purpose of this modification is to clarify the Grid Code with regard to the treatment of Virtual Impedance within a Grid Forming Plant.

What is the issue?

National Grid ESO implemented Grid Code GC0137 in February 2022 following Ofgem's approval. As a follow-up, the ESO in coordination with national and international stakeholders published a GB Grid Forming Best Practice Guide in April 2023. One of the widely debated topics of concern highlighted by group members was on the restriction of using a real impedance within a Grid Forming Inverter (GBGF-I). This restriction was initially introduced through the GC0137 proposal due to the concerns over increased stability risk. Based on the findings of the Best Practice Group, and the need to undertake compliance studies (network frequency perturbation plots or equivalent) to ensure there are no negative interactions with the total system or other Users plant and apparatus, it was agreed that the use of a virtual impedance could be permitted. Rather than restricting the type of impedance used, it was proposed that the Grid Code should focus on the performance of the converter output rather than the method of achieving the requirement against the backdrop of ensuring a Grid Forming Converter would not result in negative interactions with the Total System or other Users connected to the Total System.

What is the solution and when will it come into effect?

Proposer's solution: It is proposed to make minor changes to the European Connection Conditions (ECC) and the Glossary & Definitions within the Grid Code to require only an internal impedance rather than specifying that the impedance comprises of real physical values. N.B. Changes will be also reflected in the ESO's Guidance Notes for Grid Forming Plant for relevant developers and manufacturers.
Implementation date: 05 July 2024
Panel determination: The Panel has determined unanimously that the Proposer's solution is implemented.

What is the impact if this change is made?

This modification is expected to have a low impact on generators, manufacturers, and interconnectors and if anything will result in greater flexibility and cost savings for manufacturers and developers.

Interactions

No interactions have been identified with other live modifications.

What is the issue?

National Grid ESO implemented Grid Code GC0137 in February 2022 following Ofgem's approval. As a follow-up, the ESO's GB Grid Forming Best Practice Group further co-developed National Grid ESO's GB Grid Forming Best Practice Guide with a wide range of external stakeholders in the UK and wider afield. Its key aims being:

a. Provide the necessary guidance on the existing Legal Text following Grid Code Modification GC0137*.
b. Identify any potential Grid Code modifications required to facilitate future GB Grid Forming applications.
c. Appropriately capture good practice and suggestions from a wide range of members of the GBGF Best Practice Group for future improvements of the GB Grid Code.

Note*: For the avoidance of doubt, this GB Grid Forming Best Practice Guide should be used in conjunction with GC0137 rather than as a standalone document.

In line with (b), one of the widely debated topics of concern highlighted by group members was the restriction which prevented the use of a Virtual Impedance within a GBGF Inverter (GBGF-I).

Rather than restricting the type of impedance used, it was proposed that the Grid Code should focus on the performance output of the converter rather than the method of achieving the requirement (against the backdrop of ensuring a Grid Forming Converter would not result in negative interactions with the Total System or other Users connected to the Total System).

As the power system variables that are required to be complied with are already captured within the Grid Code requirements, together with the information in the GB Best Practice Guide and the ESO's Guidance Notes for Grid Forming Plant, the ESO and wider industry stakeholder community agree that the Virtual Impedance restriction can be removed without loss of system security.

Why change?

Allowing the GBGF-I's impedance to include a combination of physical and Virtual Impedances will enable a manufacturer to design and build a system which has a much greater level of flexibility whilst also resulting in cost savings. This will provide a more stable network and prevent unnecessary exclusion of some converters from the market.

ESO have also reviewed the European Network of Transmission System Operators' (ENTSO-E) Proposed Requirements for Generators (RfG) 2.0 during the ENTSO-E consultation stage in addition to the European Regulators (ACER) post consultation comments, and this potential change would result in greater consistency and harmonisation.

As discussed, and commonly agreed within the ESO's GB Grid Forming Best Practice Group, which included a comprehensive representation from the UK and further afield*, the following points were noted:

- The equivalent Internal Voltage Source should be defined as a Grey Box rather than a White Box (Grey Box and White Box are defined as Model approaches as a Black Box is also used within the Grid Code and EMT

modelling section. RMS model is also classed as Grey Box), where its functionality & performance as well as inputs/outputs should be clearly defined. The proposal of a Grey Box has been widely supported by stakeholders during the GB Grid Forming Best Practice Group discussions and individual stakeholder engagement during the consultation purposes.

- The Internal Voltage Source should be defined as the Grey Box so the clause, definition and figures relevant to Virtual Impedance should be removed.

*Note:- For details of those stakeholders, please see the Section of "Acknowledgements" (Pages 5-6) of GB Grid Forming Best Practice Guide in the Reference as listed in this form.

What is the solution?

It is proposed to make minor changes to the European Connection Conditions (ECC) and the Glossary & Definitions within the Grid Code to require only an internal impedance rather than specifying that the impedance comprises of real physical values. N.B. Changes will also be reflected in the ESO's Guidance Notes for Grid Forming Plant for relevant developers and manufacturers.

Workgroup considerations

The Workgroup convened 3 times to discuss the perceived issue, detail the scope of the proposed defect, devise potential solutions and assess the proposal in terms of the Applicable Objectives.

Consideration of the Proposer's solution

The Proposer shared background information as to the origin of the proposal and suggestions from the GB Grid Forming Best Practice Group that a combination of virtual and physical impedance would be of benefit to developers and potentially the end consumer in reducing costs and providing greater flexibility.

The White/Grey box definition

The proposed legal text changes to the Grid Code Glossary (for 'Internal Voltage Source' or IVS) and Grid Code section ECC 6.3.19.3 were shared with the Workgroup.

In response to a Workgroup member's question, it was clarified by an ESO engineer in the meeting that reference to a 'grey box' versus a 'white box' definition was not critical to the solution (as the solution focusses on the performance requirements rather than this definition).

Benefits of removing the restrictions

An ESO observer (a Subject Matter Expert) outlined the importance of the solution for allowing manufacturers more freedom by removing restrictions, and therefore making it easier and more flexible to meet the requirements. The benefits were expressed as cost savings (through to the consumer) and consistency with European proposals (via RFG 2.0 which includes a Grid Forming capability) based on the recent consultation is proposed to be introduced in 2025 with a three-year implementation period). Please see the GB Grid Forming Best Practice Guide. It was noted that while the exact EU drafting is not finalized, this modification should ensure greater consistency between the proposed European proposals and the GB Grid Forming requirements.

Comprehensive review of potential impacts

A Workgroup member questioned the impact of the solution on other users, for example if software fails, and whether the solution would set a precedent for a virtual impedance to be introduced to other parts of the system. The ESO observer confirmed that in relation to other users, the analysis techniques and compliance terms reviewed as part of the GB Grid Forming Best Practice Group's work should mitigate the impact on the Total System and other Users. In relation to the use of a virtual impedance on other areas of the system, it was confirmed that the scope for GC0163 was narrowly set to grid forming only and didn't prevent physical impedances from still being used (GC0163 will just allow virtual impedance to be used within the Grid Forming solution whereas it is currently prohibited). It was noted that a physical impedance will always be a significant part of the system and cannot be totally replaced by a virtual impedance. This is on the basis that in an electronic converter, the power electronic switches (Insulated Gate Bipolar Transistors (IGBTs)) simply switch the power waveform into a set of pulses and since it is not possible to change the current flowing through an inductance instantaneously, some form of real impedance is required to ensure a sine wave is developed at the output. However, since a transformer (which has its own natural impedance - generally this is far more inductive than resistive) is generally installed between a Power Electronic Converter and the System at the Grid Entry Point or User System Entry Point, then it permits developers and manufacturers to use a virtual impedance within the converter itself which provides for significant flexibility and cost saving.

Virtual: Physical Impedance Ratios

Workgroup members expressed that from an Original Equipment Manufacturer (OEM) perspective, manufacturers welcomed this change which would introduce more flexibility and cost savings. An OEM Workgroup member (for Static Synchronous Compensators – STATCOMs) noted that a virtual impedance allows STATCOMS to perform better for the grid. An OEM Workgroup member (for wind turbines) noted that a reasonable ratio of virtual to physical impedance was needed as available studies imply that too much virtual impedance would cause instability. They suggested that performance tests would be important for compliance to check that the right ratio between virtual and real impedances has been applied. Performance techniques for assessing these issues such as Network Frequency Perturbation (NFP) plots are described in the GB Grid Forming Best Practice Guide.

A Workgroup member questioned whether there will be simulations to offer guidance on the virtual/physical ratio to apply, to which the ESO observer recommended the Workgroup review the GB Grid Forming Best Practice Guide (page 30) which covers these issues. Additional material relating to real/virtual impedance is detailed in the reference section of this document.

Stability modelling

A Workgroup member asked whether the ESO were considering Electromagnetic Transient (EMT)-type modelling/simulations for proof of stability, to which the ESO confirmed this to be the case as EMT modelling is a requirement in the Grid Code (PC.A.9) for new plant.

The Chair checked with the Workgroup members involved with the initial Panel discussions for this modification that discussions had been sufficient to address the Panel's questions. This was confirmed, with the caveat that wider consultation was needed to gauge if any other parties may be affected by the solution.

The Chair invited the Workgroup to raise any cross-code implications that were applicable but had not yet been considered. No suggestions were made.

The Workgroup considered whether removing the virtual impedance restriction would conflict with the specified Self Governance criteria and concluded that it would not.

Workgroup consultation summary and post Workgroup Consultation discussions

The Workgroup held their Workgroup Consultation between 22 January 2024 and 12 February 2024 received 4 responses. The full responses and a summary of the responses can be found in Annex 5.

- ***Meeting Applicable Objectives:*** 2 of 4 Respondents felt that the Original better facilitated Objectives a, b and c only, one Respondent believed the Original better facilitated Objectives a, b, c and d, and one further Respondent provided no response to which Objectives would be better facilitated by the Original due to lack of clarity on how performance will be assessed (see Concerns point below).
- ***Implementation approach:*** 4 of 4 Respondents supported the proposed implementation approach.
- ***Alternatives:*** No Respondents noted that they would raise Alternative Requests.
- ***Concerns:*** One Respondent, a supplier, expressed concerns with removing the requirement for real impedance due to being unclear from the GB Grid Forming Best Practice Guide how pass/fail limits will be assessed. Examples were given as to areas requiring clarity and possible effects of virtual impedance. This Respondent (along with the second supplier Respondent) noted that they had experience with virtual vs real impedance control (the System Operator's Respondent noting that their experience was via findings of the GB Grid Forming Best Practice Guide).
  The Workgroup's response: This concern was discussed at length by the Workgroup and the majority view was that it is a compliance issue and would not prevent the use of a virtual impedance in future Grid Forming Plants, especially on the basis that the current Grid Code requires developers to ensure their plant and apparatus does not have any negative consequences to other User's or the System itself.
- ***Business impacts:*** 4 of 4 Respondents noted that the change will impact their business (two suppliers, a generator and the System Operator). A supplier Respondent noted that the change would provide flexibility and clarity for GBGF solutions (note: this was a separate response to that questioning how limits will be assessed).
- ***Modification title:*** 4 of 4 Respondents felt the title of the modification was a fair reflection of the modification (with one Respondent noting that it could be more explicit).
- ***Other comments:***
  - One Respondent felt that wording of ECC.6.3.19.3 (v)(b) should also be changed to reflect this change ("Operating as a voltage source behind a real reactance" to "Operating as a voltage source behind an impedance").
    The Workgroup's response: The Workgroup agreed to this change, and it is reflected in the legal text.

- One Respondent felt that legal text should be more explicit about allowing virtual impedance and that they were planning several projects using GBGF-I technology.
  The Workgroup's response: The Workgroup discussed this concern and amended the definition of Internal Voltage Source in the Glossary & Definitions legal text to make it more explicit.
- One Respondent noted their belief that the change would provide flexibility leading to cost savings through to end users, better competition and more converter-based plants would support the drive towards net zero. Another Respondent felt the change would bring a positive change to their business through increased harmonisation and flexibility.

Legal text

Legal text for this change can be found in Annex 4.

What is the impact of this change?

As the power system variables that are required to be complied with are already captured within the Grid Code requirements and the GB Best Practice Guide together with the ESO's Guidance Notes for Grid Forming Plant, the ESO and wider industry stakeholder community agree that the Virtual Impedance restriction can be removed without loss of system security.

Proposer's assessment against Grid Code Objectives	
Relevant Objective	**Identified impact**
(a) To permit the development, maintenance and operation of an efficient, coordinated and economical system for the transmission of electricity	**Neutral**
(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);	**Positive** Allowing GB Grid Forming Inverters (GBGF-I's) that comprise a Virtual Impedance will increase flexibility and reduce costs thereby allowing a more competitive market.
(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;	**Positive** The use of a Virtual Impedance provides greater flexibility and if tuned appropriately may result in an enhanced stability performance. It also results in greater flexibility and cost savings.
(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	**Neutral**

(e) To promote efficiency in the implementation and administration of the Grid Code arrangements	**Neutral**

Workgroup Vote

The Workgroup met on 27 February 2024 to carry out their Workgroup vote. The full Workgroup vote can be found in Annex 6. The table below provides a summary of the Workgroup members view on the best option to implement this change.
The Applicable Grid Code Objectives are:

Grid Code

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

The Workgroup concluded unanimously that the Original better facilitated the Applicable Objectives than the Baseline.

Option	Number of voters that voted this option as better than the Baseline
Original	7

Code Administrator Consultation Summary

The Code Administrator Consultation was issued on the 02 April 2024 closed on 02 May 2024 and received 5 responses. A summary of the responses can be found in the table below, and the full responses can be found in Annex 8. Interconnector parties were contacted to invite contributions to the consultation, but no responses were received.

Code Administrator Consultation summary	
Question	
Do you believe that the GC0163 Original Proposal better facilitates the Grid Code Applicable CUSC Objectives?	Three respondents stated that the change would better facilitate objective A. Three stated objective C. And all five respondents stated objective B.
Do you support the proposed implementation approach?	Four respondents supported the implementation approach, as by removing the virtual impedance restriction, this will provide greater design flexibility for more cost-effective designs of grid forming converters. One respondent did not support the implementation in its current form but acknowledged the benefits virtual impedances can bring.
Do you have any other comments?	One respondent found the modification provides a foundation for improvement. Another provided suggestions for future work on grid forming controls, such as testing, damping, inertia, switching, and coordination. The respondent who was not supportive of the implementation stated that the virtual impedance can be difficult to characterize, implement and justify in terms of cost and performance for power converters. Four factors were identified by them that make the controller impedance characterization more complex: the dependence on the operating point, the discrete-time behaviour, the fault-ride through characteristic, and the safety integrity level. By reducing the physical impedance in the power converters, the respondent noted that this may require faster and more reliable protection systems to limit the fault current and prevent damage to the converter equipment. The economic benefits were questioned as it may introduce additional system risk, larger cooling system requirements, and higher voltage demand for the power converters. It was suggested that a cost-benefit analysis is needed to support the CAPEX and OPEX reduction claims. It was pointed out that the method of synthesizing an impedance is likely to be proprietary and protected by the intellectual property rights of the control algorithms, which may limit the information sharing and specification, and increase the costs for the stakeholders to ensure the system-level transient response.

Legal text issues raised in the consultation
The ESO Code Administrator Consultation response suggested an amendment to remove a legacy comma in the Legal Text for the definition of Internal Voltage Source in the Glossary and Definitions.

Panel Determination vote

The Panel met on the 30 May 2024 to carry out their determination vote.
They assessed whether a change should be made to the Grid Code by assessing the proposed change and any alternatives against the Applicable Objectives.

Panel comments on Legal text

Ahead of the vote taking place, the Panel considered the legal text amendments proposed as part of the Code Administrator Consultation and agreed that they were typographical. The proposed changes can be found in Annex 9.

Vote 1: Does the Original facilitate the objectives better than the Baseline?
Panel Member: **Alan Creighton, Network Operator Representative**

	Better facilitates AO (a)?	Better facilitates AO (b)?	Better facilitates AO (c)?	Better facilitates AO (d)?	Better facilitates AO (e)?	Overall (Y/N)
Original	Neutral	Yes	Yes	Neutral	Neutral	Yes
Voting Statement						
The proposal provides flexibility for manufacturers to implement grid forming technology.						

Panel Member: **Alastair Frew, Generator Representative**

	Better facilitates AO (a)?	Better facilitates AO (b)?	Better facilitates AO (c)?	Better facilitates AO (d)?	Better facilitates AO (e)?	Overall (Y/N)
Original	Neutral	Yes	Yes	Neutral	Neutral	Yes
Voting Statement						
This enables developers to use both real and virtual impedance's to get the optimum solution which still has to be compliant with code requirements and simulations.						

Panel Member: **Antony Johnson, ESO Representative**

	Better facilitates AO (a)?	Better facilitates AO (b)?	Better facilitates AO (c)?	Better facilitates AO (d)?	Better facilitates AO (e)?	Overall (Y/N)
Original	Yes	Yes	Yes	Neutral	Neutral	Yes
Voting Statement						
We support this modification. By removing the obligation to have a real impedance between the Internal Voltage Source of a Grid Forming Converter and the Grid Entry Point or User System Entry Point (if Embedded) we believe this provides greater flexibility and cost savings to developers and manufacturers. In this regard we believe this modification will provide greater efficiency which will deliver cost savings for end consumers, it will improve competition in providing						

flexibility for developers and it will help facilitate the volume of Grid Forming technology across GB which is an industry pre-requisite for promoting net zero.
We believe this modification facilitates Grid Code objectives A, B and C as indicated above. We believe this modification facilitates Grid Code objectives A, B and C as indicated above.

Panel Member: **Darshak Shah, Generator Representative**

	Better facilitates AO (a)?	Better facilitates AO (b)?	Better facilitates AO (c)?	Better facilitates AO (d)?	Better facilitates AO (e)?	Overall (Y/N)
Original	No	Yes	Yes	Neutral	Neutral	Yes
Voting Statement						
This change enables to remove barriers and better facilitation under grid code requirement.						

Panel Member: **Graeme Vincent, Network Operator Representative**

	Better facilitates AO (a)?	Better facilitates AO (b)?	Better facilitates AO (c)?	Better facilitates AO (d)?	Better facilitates AO (e)?	Overall (Y/N)
Original	Yes	Yes	Yes	Neutral	Neutral	Yes
Voting Statement						
The proposed modification allows additional flexibility in the provision of how the impedance is provided whilst aiming to ensure that the same level of performance requirements are maintained.						

Panel Member: **John Harrower, Generator Representative**

	Better facilitates AO (a)?	Better facilitates AO (b)?	Better facilitates AO (c)?	Better facilitates AO (d)?	Better facilitates AO (e)?	Overall (Y/N)
Original	Yes	Yes	Neutral	Neutral	Neutral	Yes
Voting Statement						
This modification removes the restriction on the use of virtual impedance of grid forming plant within the grid code requirements.						

Panel Member: **Robert Longden, Supplier Representative**

	Better facilitates AO (a)?	Better facilitates AO (b)?	Better facilitates AO (c)?	Better facilitates AO (d)?	Better facilitates AO (e)?	Overall (Y/N)
Original	Yes	Neutral	Neutral	Neutral	Neutral	Yes
Voting Statement						
GC0163 removes an unnecessary restriction regarding GBGF installations and therefore promotes more security and efficiency in Grid operation						

Panel Member: **Richard Woodward, Onshore Transmission Representative**

	Better facilitates AO (a)?	Better facilitates AO (b)?	Better facilitates AO (c)?	Better facilitates AO (d)?	Better facilitates AO (e)?	Overall (Y/N)

Original	Neutral	Yes	Yes	Neutral	Neutral	Yes
Voting Statement						
We support the proposer's assessment of the modification, which seeks to more proportionately and flexibly support compliance of technical obligations by Users.						

Panel Member: **Sigrid Bolik, Generator Representative**

	Better facilitates AO (a)?	Better facilitates AO (b)?	Better facilitates AO (c)?	Better facilitates AO (d)?	Better facilitates AO (e)?	Overall (Y/N)
Original	Yes	Yes	Yes	Neutral	Neutral	Yes
Voting Statement						
The change will help to allow for technical improvements in the area to be implemented to fulfil stability requirements.						

Vote 2 – Which option best meets the Applicable Grid Code Objectives?

Panel Member	BEST Option?	Which objectives does this option better facilitate? (If baseline not applicable).
Alan Creighton	Original	B, C
Alastair Frew	Original	B, C
Antony Johnson	Original	A, B, C
Darshak Shah	Original	B, C
Graeme Vincent	Original	A, B, C
John Harrower	Original	A, B
Robert Longden	Original	A
Richard Woodward	Original	B, C
Sigrid Bolik	Original	A, B, C

Panel conclusion
The Panel has determined unanimously that the Proposer's solution is implemented.

When will this change take place?

Implementation date
This modification will be implemented on 05 July 2024, 5 working days after the appeals window closes, providing no objections have been raised. The appeals window will run from 10 June 2024 to 28 June 2024.

Date decision required by
A decision was required at the Grid Code Review Panel on 30 May 2024.

Implementation approach
No internal systems or process changes will be required. Changes will be reflected in the ESO's Guidance Notes for Grid Forming Plant for relevant developers and manufacturers.

Interactions

☐Grid Code ☐European Network Codes	☐BSC ☐ EBR Article 18 T&Cs[1]	☐STC ☐Other modifications	☐SQSS ☐Other

No interactions have been identified with other live modifications.

The modification follows the development of National Grid ESO's GB Grid Forming Best Practice Guide and the implementation of GC0137 "Minimum Specification Required for Provision of GB Grid Forming (GBGF) Capability (formerly Virtual Synchronous Machine/VSM Capability).

Acronyms, key terms and reference material

Acronym / key term	Meaning
ACER	Agency for the Cooperation of Energy Regulators
BSC	Balancing and Settlement Code
CUSC	Connection and Use of System Code
EBR	Electricity Balancing Regulation
ECC	European Connection Conditions
EMT	Electromagnetic Transient
ENTSO-E	European Network of Transmission System Operators
ESO	Electricity System Operator
EU	European Union
GBGF	Great Britain Grid Forming
GBGF-I	Great Britain Grid Forming Inverter
GC	Grid Code
IGBT	Insulated Gate Bipolar Transistors
NFP	Network Frequency Perturbation
OEM	Original Equipment Manufacturer
RfG	Requirements for Generators
STATCOM	Static Synchronous Compensators
STC	System Operator Transmission Owner Code
SQSS	Security and Quality of Supply Standards
T&Cs	Terms and Conditions

Reference material

- ESO's GC0137 "Minimum Specification Required for Provision of GB Grid Forming (GBGF) Capability (formerly Virtual Synchronous Machine/VSM Capability)" as implemented in February 2022.
- ESO's GB Grid Forming Best Practice Guide as issued in April, 2023.

[1] If the modification has an impact on Article 18 T&Cs, it will need to follow the process set out in Article 18 of the Electricity Balancing Regulation (EBR – EU Regulation 2017/2195) – the main aspect of this is that the modification will need to be consulted on for 1 month in the Code Administrator Consultation phase. N.B. This will also satisfy the requirements of the NCER process.

- ESO's Guidance Notes for Grid Forming Plant
- European Union Agency for the Cooperation of Energy Regulators (ACER) draft amendments to the Network Code on Requirements for Generators
- Unified Sequence Impedance Models of Synchronous Generator- and Virtual Oscillator-Based Grid-Forming Converters
- On the Passivity of Grid-Forming Converters – Role of Virtual Impedance
- Unified Modeling and Analysis of Sequence Impedance of Grid-Forming Converters with Multi-loop Control
- Sequence Impedance Modeling and Stability Comparative Analysis of Voltage-Controlled VSGs and Current-Controlled VSGs

Annexes

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