EMT Model Requirements for Existing Generators

ESO

Background

- As Great Britain's (GB) power system moves towards net zero carbon operation, the number of Inverter-Based Resources (IBR) is expected to increase and the amount of synchronous generation in the grid to decline which will significantly change the characteristics of the GB network.

- These changes giving rise to the potential control interactions between the devices across the network leading to risks of oscillations and inverter stability.

- Electromagnetic Transient (EMT) analysis is important for investigating the dynamics of converters, control interactions between the devices in the network, detecting system oscillations, commutation failure analysis, inverter stability analysis and identifying transient phenomena such as Transient Over Voltage (ToV).

- Root Mean Squared (RMS) simulations might not be able to capture or be capable of highlighting these issues adequately and they have limitations on modelling fast controls within the converters and non-fundamental frequency phenomenon.

What is the Ask?

- With the Grid Code GC0141 implementation, Users with completion date on or after September 2022 need to submit EMT models to the ESO.

- To carry out analysis such as system oscillation, inverter stability, ToV analysis, EMT models for generators with a completion date prior to September 2022 would be required.

- **Without these additional models, it could lead to unnecessary investment by the users or the TO, significant increase in constraint cost, single event leading to tripping of number of generators and could ultimately lead to loss of supply.**

- The generic EMT models may not be the correct representation of Inverter Based Resources (IBR) control elements such as Phase Locked Loop (PLL) control behaviour.

- **ESO is suggesting a Grid Code change that mandates all Users to provide EMT models for their plants.**

- ESO fully appreciate the importance of IP of manufacturers, however, it should not sit above the integrity of national infrastructure

- **ESO believe that the most efficient way to do this is, whilst remaining considerate of IP, is through a code modification.**

Enablers

- PC.A.6.1.3 suggest that at The Company's reasonable request, EU Code users expected to submit EMT simulations. Hence it is expected that these Users should have developed EMT models already.

> of identifying the best way in which **The Company's** requirements can be met. In respect of **EU Code User**(s) only, **The Company** may request the need for electromagnetic transient simulations at **The Company's** reasonable request. **Users** with **EU Grid Supply Points** may be required to provide electromagnetic transient simulations in relation to those **EU Grid Supply Points** at **The Company**'s reasonable request.

- EU Code Users, in general it covers for generators connected from late 2018
- For all HVDCs, already BCA requests for EMT models
- With the existing GC requirements, synchronous generators to provide shaft data when requested by The Company for SSTI studies

Need Case Examples

- **Scotland Region**
  - In the recent years system oscillation of 1Hz to 8 Hz have been reported in the Scotland region, with the declining conventional synchronous generations and increasing IBR sources.
  - To evaluate the source of oscillations and to plan the mitigating actions to eliminate the oscillation issues, EMT models are required.
  - In addition to the oscillation analysis, inverter stability, commutation failure of LCC HVDC, TOV analysis to be carried out, for region with high penetration of IBR.

- **South East Coast Region**
  - Region with high penetration of power electronic devices; LCC HVDC, VSC HVDC, Type 4 wind farms, hybrid STATCOMs so on
  - To gain confident in planning ESO need to carry out analysis on system oscillation, inverter stability, commutation failure of LCC HVDC and TOV analysis, for a region with such a high penetration of IBR.

- **The UK government has set out ambition to deliver 50GW of offshore wind by 2030**
  - Future IBR, such as offshore HVDC sources, are going to be connected to locations closer to already existing IBR resources and/or synchronous generator, then possible Sub-synchronous Torsional Interaction (SSTI) and Sub-Synchronous Control Interactions (SSCI) need to be evaluated.

Possible Approaches

Option	Comments
Option 1: GC modification can mandate **all the existing generators** (connected before 1st September 2022) to provide EMT models	• Number of generators connected long time ago, mainly conventional synchronous generators, may not have EMT model or expertise within company to provide EMT model. This was discussed during the GC0141 modification with Users concerns that models could be difficult to produce for older plant • Small number of WF plants may have the issue. • Users may concerned about the cost for developing EMT model to represent their plants, if it is not already available
Option 2: GC modification can mandate **User Plant Specific** EMT model submission **from Users of IBR technology** connected before 1st September 2022	• This approach can reduce the risk of very old plants, mainly synchronous generators, to develop EMT models
Option 3: GC modification can **mandate EMT model submission for all EU Code Users** connected before 1st September 2022 and **The Company can request other Users** connected before 1st September 2022 to provide EMT model within X months	• Based on the existing PC.A.6.1.3, EMT simulations should be submitted by EU Code Users by the request from The Company • Many generators (generators connected late 2018) may fall into this category
Option 4: GC modification to reflect that **The Company can request EMT models from all Users** connected before 1st September 2022 and Users are expected to submit their models within X months	• ESO can target and prioritise • Not yet sure about the months (may be 6 months)


Thanks

GCDF – Changes for Virtual Impedance of Grid Forming Plant

6th September, 2023

ESO

Background

As deeply discussed/consulted, concluded and commonly agreed within ESO's GB Grid Forming Best Practice Group including comprehensive stakeholders with a good mix of background in the UK and wider*:

- For the position of ESO, the equivalent Internal Voltage Source should be defined as a Grey Box rather than a White Box, where its functionality & performance as well as inputs/outputs should be clearly defined. Such a proposal of Grey Box has been widely supported by comprehensive external stakeholders during Best Practice Group discussions and individual stakeholder engagements for consultation purpose.
- For the ESO's position, the Internal Voltage Source should be defined as the Grey Box so the clause, **definition and figures as relevant to Virtual Impedance in current Grid Code should be removed**.
- Such proposal with updated wordings have been internally reviewed.

Note*: For details, please see the reference as listed.
ESO's GB Grid Forming Best Practice Guide as issued in April, 2023
URL: https://www.nationalgrideso.com/document/278491/download

GC Changes as Proposed

Internal Voltage Source or **IVS**	For a **GBGF-S**, a real magnetic field, that rotates synchronously with the **System Frequency** under normal operating conditions, which as a consequence induces an internal voltage (which is often referred to as the Electro Motive Force (EMF)) in the stationary generator winding that has a real impedance. In a **GBGF-I**, switched power electronic devices are used to produce a voltage waveform, with harmonics, that has a fundamental rotational component called the **Internal Voltage Source (IVS)** that rotates synchronously with the **System Frequency** under normal operating conditions. For a **GBGF-I** there must be an internal impedance ~~with only real physical values,~~ between the **Internal Voltage Source** and the **Grid Entry Point** or **User System Entry Point**. ~~For the avoidance of doubt, a virtual impedance, is not permitted in GBGF-I.~~

ECC.6.3.19.3 As noted in ECC.6.3.19.2, **Grid Forming Capability** is not a mandatory requirement, however where a **User** (be they a **GB Code User** or **EU Code User**) or **Non-CUSC Party** wishes to offer a **Grid Forming Capability**, then they will be required to ensure their **Grid Forming Plant** meets the following requirements.

(i) The **Grid Forming Plant** must fully comply with the applicable requirements of the Grid Code including but not limited to the **Planning Code** (**PC**), **Connection Conditions** (**CC**'s) or **European Connection Conditions** (**ECC**'s) (as applicable), **Compliance Processes** (**CP**'s) or **European Compliance Processes** (**ECP**'s) (as applicable), **Operating Codes** (**OC**'s), **Balancing Codes** (**BC**'s) and **Data Registration Code** (**DRC**).

(ii) Each **GBGF-I** shall comprise an **Internal Voltage Source** behind an impedance ~~and reactance. For the avoidance of doubt, the reactance between the **Internal Voltage Source** and **Grid Entry Point** or **User System Entry Point** (if **Embedded**) within the **Grid Forming Plant** can only be made by a combination of several physical discrete reactances. This could include the reactance of the **Synchronous Generating Unit** or **Power Park Unit** or **HVDC System** or **Electricity Storage Unit** or **Dynamic Reactive Compensation Equipment** and the electrical **Plant** and **Apparatus** connecting the **Synchronous Generating Unit** or **Power Park Unit** or **HVDC System** or **Electricity Storage Unit** (such as a transformer) to the **Grid Entry Point** or **User System Entry Point** (if **Embedded**).~~

Next Steps

- ESO to communicate with members of GB Grid Forming Best Practice Group for awareness of those Grid Change minor changes for virtual impedance in line with post-delivery plan of GBGF Best Practice Group.
- Internal communications across ESO to raise such awareness if relevant to any future business projects/programmes.

Q&A

Thanks for your attention!

Any Question?