

Expert Workgroup on Fast Fault Current Injection stage 1 Terms of Reference

Governance

1. The need case to establish a Next Steps Expert Technical Workgroup Supporting Fast Fault Current Injection (FFCI) and associated control including Virtual Synchronous Machine (VSM) approaches was agreed at the 12th January 2017 Grid Code Development Forum (GCDF) following presentation of the proposal.
2. The work will be divided into two stages: stage 1 workgroup shall work in accordance with the Terms of Reference and shall be responsible for preparing a draft Grid Code Modification Proposal(s) in accordance with the timetable set by the chair.
3. Stage 2 Workgroup will work under the Grid Code Review Panel (GCRP) governance once the modification proposal(s) is approved by GCRP to proceed.

Background

In 2017, National Grid consulted on its proposals for Fast Fault Current Injection and Fault Ride Through (GC0100) as part of the implementation of the RfG and HVDC European Network Codes. As part of this consultation, National Grid proposed three options which included:-

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| Option 1 | the requirement for enhanced converter control performance similar to that of a Synchronous machine, for implementation by 2021 – the so called Virtual Synchronous Machine (VSM), |
| Option 2 | the use of currently available converter control technology with a ceiling current of 1.25pu |
| Option 3 | The use of currently available converter control technology with a ceiling current of 1.0pu. |

In preparation for this work, National Grid had run numerous studies which were documented as part of this consultation. This consultation is available from the following link:-

https://www.nationalgrid.com/sites/default/files/documents/Final%20Workgroup%20consultation_0.pdf

As part of the consultation, National Grid advised that they would be happy with any of the above options, but if either option 2 or 3 were selected, they would wish to set

up an expert group to look at enhanced converter control strategies similar to the VSM but in addition to market based solutions, including the use of synchronous compensators.

The reason for this is two-fold. Firstly, based on National Grid's Future Energy Scenario's (FES) and the System Operability Framework (SOF), there is a rapid decline in the volume of transmission connected Synchronous Generation which results in concerns over issues such as declining synchronising torque, falling levels of inertia, low short circuit levels, depressed retained voltage profiles under fault conditions, ability for generation connected to healthy circuits under fault conditions to name but a few. Secondly, the majority of converter based technologies use a control strategy based on a phase locked loop (PLL) which have number of shortcomings from a System perspective. There is increasing concern over the use of the Phase Locked Loop (PLL) as a converter control strategy and this issue has been documented in the SOF.

<https://www.nationalgrid.com/sites/default/files/documents/Phase%20locked%20loop%20FINAL.pdf>

Furthermore, many converter strategies inject current into the network unlike synchronous generators which largely behave as voltage source behind impedance. As a consequence, they don't contribute to reducing negative and zero sequence imbalance or help with harmonics. Current sources have also been shown to be less stable in models and real applications.

Following the consultation, there was an overwhelming response for Option 3, largely as this option is already technically available in today's market. As a result, and in line with the GC0100 consultation, National Grid is therefore proposing to set up an expert group to examine and address these issues.

Stage 1 Workgroup Scope:

This stage will:-

- 1) Evaluate option 1 of GC0100, enhanced converter control performance similar to that of a Synchronous machine
- 2) Review international practice (including VSM) of advanced converter control strategies
- 3) Understand the technical feasibility and costs of such developments
- 4) Comprise of national and international experts who have knowledge and experience of such technologies including manufacturers
- 5) Develop a clear specification for converter performance post 1 January 2021
- 6) Understand the application of such technologies to both small installations (less than 1MW) up to the largest installations which could be in the GW range.

- 7) Seek to develop a cost for the development and application of the above options from the smallest to largest plants.
- 8) Develop a draft Grid Code modification proposal to be proceeded in stage 2

In addition, the following specific areas will also be examined:-

Fault Ride Through

- Active power recovery
- Fast Fault Current Injection
- Low Voltage Blocking

Voltage and Reactive Power

- Voltage stability
- Provision of active power over a range of system voltage changes
- Angular Stability
- Voltage and Frequency ranges
- Inertial response to combined frequency and voltage disturbances
- Reactive current delivery during and after a fault in addition the phase relationship with the System.
- Transient voltage and excitation control

Emergency and Restoration

- Ensuring that the required performance as described above does not adversely impact the performance of the system over a range of conditions such as islanding, Low Frequency Demand Disconnection or the ability to deliver a viable Black Start Strategy.

Scenarios

- Examination and studies conducted under System Operating conditions, both normal and abnormal against typical demand and generation scenarios in the early 2020's.

Stage 1 of the workgroup will not consider:-

1. Options for implementation ahead of 1st Jan 2021 other than to clarify any requirements that are unclear as part of option 3 proposed under GC0100.
2. Modifications to existing Frequency, Voltage and Angular stability requirements or ranges.
3. Specification for multi-terminal offshore HVDC systems or for users connected to remote end HVDC- systems.
4. Market framework, market impact, cost benefit or commercial optimisation matters, nor any other matters as reserved for the Stage 2 of the work group (see below), but rather seek to provide the technical considerations.

5. Specific project designs, clarifications or advice which will continue to be managed across the period of review under existing processes between Users and National Grid within established code frameworks.

Workgroup Membership

Stage 1 is specifically aimed at examining technical solutions and will therefore comprise an expert group who have national and international experience in technical and converter based control. In particular, technical experts from manufacturers, utilities, developers, research organisations, consultants and trade associations would be welcome to join.

NGET will appoint a chair who shall act impartially and independently. NGET will also provide a technical secretary resource for the Workgroup who will handle administrative arrangements such as venue, agenda and recording actions and meeting notes. The chair and the secretary may appoint alternates to attend a meeting in their place.

NGET shall ensure as far as possible that an appropriate cross-section of relevant experience interests and expertise is able to be represented on the workgroup.

Workgroup Meetings

The Workgroup will meet in person, but may decide to hold meetings by teleconference with agreement of the chair and a majority of the membership. An agenda and any supporting material for the meeting will be issued to the Workgroup members as required to allow Workgroup members to consider these items prior to the meeting.

The frequency of the workgroup meetings shall be defined as necessary by the Workgroup chair to meet the scope and objectives. It is estimated that the workgroup will have 3 meetings and conclude in 6 months.

Deliverables

The Workgroup will provide updates to the GCRP as appropriate and on conclusion will present a report and Grid Code modification proposal as appropriate, which includes

- Detail the findings of the Group;
- Draft, prioritise and recommend changes to the Grid Code and associated documents in order to implement the findings of the Group; and
- Highlight any consequential changes which are or may be required.

Appendix 1

Indicative Scope Stage 2 (for information)

Once the draft Grid Code modification produced in stage 1 is approved by GCRP to proceed, Stage 2 workgroup will be established under normal GCRP governance to take forward the modification. The indicative works include:-

- 1) Convene a cost benefit analysis to identify the most economic and efficient solution which is fit for operating the system in the 2020's. This shall include but not be limited to:-
 - a. The application of VSM type technologies installed on all Generation, HVDC equipment and Storage technologies
 - b. The need or otherwise for fault ride through and VSM type technology for plant below 1MW
 - c. The implications and costs to the system if the specifications identified in stage 1 applied only to plant of 1MW and above
 - d. The use of market based solutions – adjusting the plant mix to ensure the requirements of the SQSS can be satisfied or the partial use of VSM type technology with various levels of de-rating permitted.
 - e. The use of synchronous compensation equipment or de-clutched Generation
 - f. The balance and costs between equipment installed by Generators, HVDC System Owners or Storage Owners and Network Licensees
 - g. Consider the balance between reserve holding, inertial response and operation of the Low Frequency Demand Disconnection Scheme.
- 2) Ensure the Cost Benefit Analysis at least uses the same scenarios developed under Phase 1 to understand the total costs of operating the system in the 2020's under both normal and abnormal conditions.
- 3) Determine the overall most economic and efficient result, either via technical solutions, market arrangements or a combination of the two. The scenarios developed in Stage 1 will be used in this process but this would not preclude additional scenarios being used in Stage 2.