Workgroup Consultation

GC0155:

Clarification of Fault Ride Through Technical Requirements

Overview: An alternative to GC0151 which addressed the Fault Ride Through (FRT) compliance process and proposed minor improvements to the FRT technical requirements. This alternative was insufficiently scrutinised as part of the GC0151 urgent modification process hence Ofgem, while rejecting it in their decision letter dated 8 November 2021, noted that it had merit and should be brought forward subsequently.

Modification process & timetable

1. **Proposal Form** – 16 December 2021
2. **Workgroup Consultation** – 07 August 2023 – 29 August 2023
3. **Workgroup Report** – 15 November 2023
4. **Code Administrator Consultation** – 28 November 2023 – 02 January 2024
5. **Draft Modification Report** – 17 January 2024
6. **Final Modification Report** – 07 February 2024
7. **Implementation** – Within 10 working days of Ofgem

Have 5 minutes? Read our Executive summary

Have 20 minutes? Read the full Workgroup Consultation

Have 30 minutes? Read the full Workgroup Consultation and Annexes.

Status summary: The Workgroup are seeking your views on the work completed to date to form the final solution(s) to the issue raised.

This modification is expected to have a: medium impact on Generators, Transmission System Operators, Interconnectors, Transmission Owners, Distribution Owners

Modification drivers: GB Compliance, Ofgem-led Code Review, System Operability, System Security, Efficiency, New Technologies

Governance route	Standard Governance modification with assessment by a Workgroup	
Who can I talk to about the change?	**Proposer:** Terry Baldwin Terry.Baldwin@nationalgrideso.com 0781 4778 118	**Code Administrator Chair**: Banke John-Okwesa Banke.john-okwesa@nationalgrideso.com 0792 9716 301
How do I respond?	Send your response proforma to grid.code@nationalgrideso.com **by 5pm on x xxxxxx 2023**	

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Executive summary

What is the issue?

This proposal is based on an alternative proposal (WAGCM2) to GC0151 *'Grid Code Compliance with Fault Ride Through Requirements (FRT)'* proposed by Drax Power Ltd to clarify the technical requirements for FRT capability set out in the Grid Code to improve consistency, accuracy and understanding and to help prevent non-compliance with the Grid Code.

This modification therefore proposes minor changes and improvements to the existing Grid Code FRT requirements as a minimum but not limited to the following:

- To clarify instances where User plant is permitted to trip where required in order to clear the fault from the transmission system.
- To amend requirements for generating maximum reactive current during faults which may be unachievable for many Generators.
- To amend post fault active power requirements to reflect that low load Generators may have greater oscillations than the requirements currently allow for.
- To provide requirements for overvoltage events following a fault.

Why change?

To enable Generators to better assess their compliance to FRT requirements, which will enhance system security during fault conditions, and to avoid unnecessary compliance proceedings following an incident where a Generator may have tripped for allowable reasons by achieving greater clarity for all parties.

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

Proposer's solution:
The sections of the code to which changes are proposed are CC.6.3.15 and ECC.6.3.15 which together form the FRT technical conditions for all applicable plant. There are several other issues within the existing legal text in the Grid Code relating to FRT – stemming from the current drafting and understanding of the legal text.

Implementation date:
10 days after authority approval.

Summary of potential alternative solution(s) and implementation date(s):

WAGCM1 In general this Alternative Modification Proposal will have the same effect as the Original Modification Proposal except that it will not be retrospective (whereas the Original would be).

What is the impact if this change is made?

No identified impacts

Commented [JOB1]: This may need to be updated since considering HVRT

Interactions

This modification proposal if implemented, will have no impacts on the EBR or on other codes.

What is the issue?

This proposal is based on an alternative proposal (WAGCM2) to GC0151 'Grid Code Compliance with Fault Ride Through Requirements'. It was proposed during the GC0151 workgroup by Drax Power Ltd and aimed to clarify the technical requirements for FRT capability set out in the Grid Code to improve consistency, accuracy and understanding and to help prevent non-compliance with the Grid Code.
Ofgem in their decision letter on GC0151 noted the views of various stakeholders and Panel members that while WAGCM2 had merit it had been insufficiently scrutinised as part of the urgent development process undertaken for GC0151. Following the implementation of GC0151, the ESO agreed to raise a modification embodying the GC0151 WAGCM2 proposals which the ESO had also broadly supported.
This modification therefore proposes minor changes and improvements to the existing Grid Code Fault Ride Through requirements as a minimum but not limited to the following:

- To clarify instances where User plant is permitted to trip where required in order to clear the fault from the transmission system.
- To amend requirements for generating maximum reactive current during faults which may be unachievable for many Generators.
- To amend post fault active power requirements to reflect that low load Generators may have greater oscillations than the requirements currently allow for.
- To provide requirements for overvoltage events following a fault.

Why change?

To enable Generators to better assess their compliance to FRT requirements, which will enhance system security during fault conditions, and to avoid unnecessary compliance proceedings following an incident where a Generator may have tripped for allowable reasons by achieving greater clarity for all parties.

What is the solution?

Proposer's solution

The sections of the code to which changes are proposed are CC.6.3.15 and ECC.6.3.15 which together form the FRT technical conditions for all applicable plant.

Commented [JOB2]: There will be additional texts due to the HVRT element

There are several issues within the existing legal text in the Grid Code relating to FRT: technical compliance issues due to the current drafting and understanding of the current legal text. The following sections explain the various issues and proposed solutions.

Clarification of Fault Ride Through Requirement

The way CC.6.3.15(a)(i) is written deals both with plant capability and actions to be taken during a fault, however, it does not clearly distinguish between either, leading to confusion.

It is suggested that the current CC.6.3.15(a)(i) is split into two sections, one dealing with the required capability CC.6.3.15(a)(i)(a) and a second section CC.6.3.15(a)(i)(b) dealing with actions to be taken during a fault.

Plant Capabilities

The new section CC.6.3.15(a)(i)(a) will only deal with plant capabilities by clarifying that the plant has to be capable of riding through the worst fault that the network could impose which is a 3-phase short circuit at the connection point which lasts for up to 140ms as shown in figure 1 below. To achieve this, the words “be design to” will be added to section CC.6.3.15(a)(i)(a) as can be seen in the legal text in appendix 1.

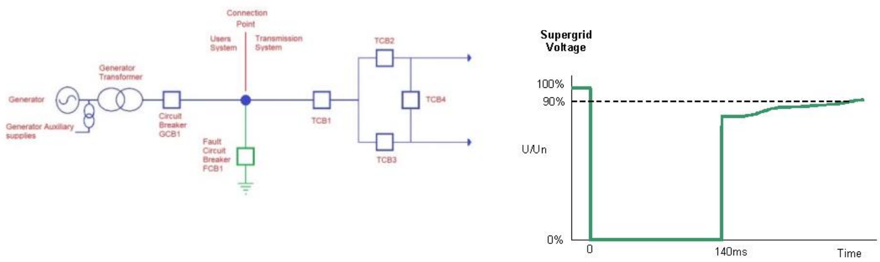


Figure 1 showing theoretical worse case fault which plant must be capable of riding though

Operating Requirements During a Fault

The new section CC.6.3.15(a)(i)(b) will specify the actions to be taken if a fault occurs by requiring that plants ride through faults in the transmission system which can be cleared by the transmission system circuit breaker as shown in figure 2 below and by adding the following text as the introduction to the section.

(b) Each **Generating Unit**, **DC Converter**, or **Power Park Module** and any constituent **Power Park Unit** thereof and **OTSDUW Plant and Apparatus** shall remain transiently stable and connected to the **System** without tripping of any **Generating Unit**, **DC Converter** or **Power Park Module** and / or any constituent **Power Park Unit**, **OTSDUW Plant and Apparatus**, and for **Plant and Apparatus** installed on or after 1 December 2017, reactive compensation equipment, for any balanced and unbalanced fault where subjected to a voltage dip at either the **Onshore Grid Entry Point** or **Interface Point** as applicable where the voltage remains either on or within the envelope shown in figure CC.6.3.15(a)(i)(a) except where:

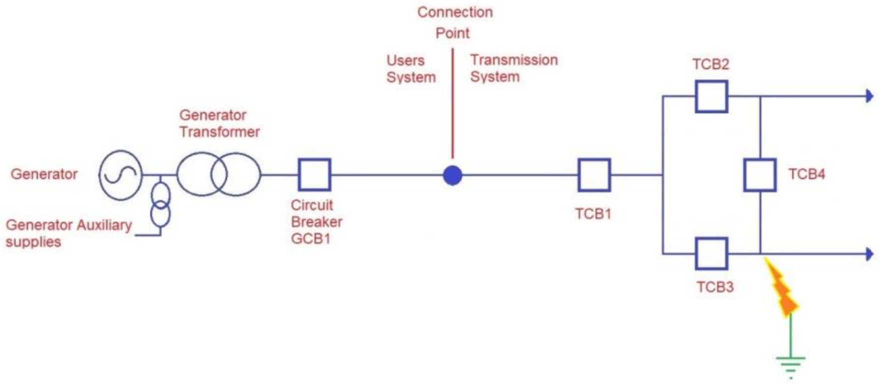


Figure 2 showing a fault which can be cleared by transmission system breakers TCB3 & 4

Whilst the introduction to this section deals with plants riding through faults as it is currently drafted in the Grid Code, it is not clear what is supposed to happen where the plant's circuit breaker has to open to clear the fault. There are concerns that the current text could be interpreted that the plant shall remain connected feeding the fault for 140ms which could lead to dangerous situations. It is clear this is not the intent, and that plant should trip during these circumstances. It is proposed that the following subclauses are added to clarify each situation where tripping is permitted.

Firstly, if the fault is on the Generator's equipment then the Generator shall be required to trip to clear the fault from the transmission system as detailed in the proposed new section CC.6.3.15(a)(ii)(b)(i) (note that this is already permitted in the ECCs), as follows: -

Power Park Module and any constituent **Power Park Unit** thereof and **OTSDUW Plant and Apparatus** shall trip to clear the fault from the **Transmission System.** The protection schemes and settings should not jeopardise **Fault Ride Through** performance as specified in CC.6.3.15.1

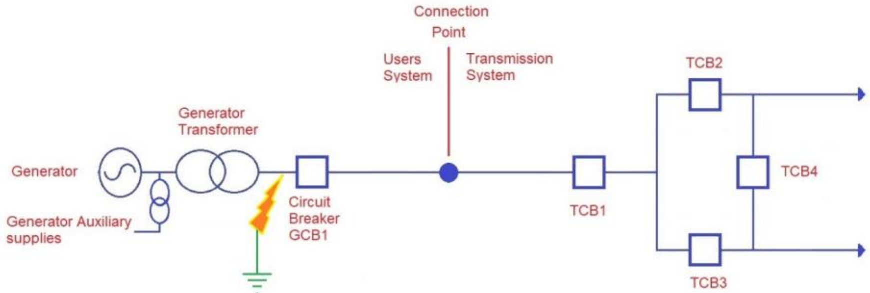


Figure 3 showing a fault which can only be cleared by generator breakers GCB1

Secondly if the location of the fault on the network that means that the fault can only be cleared by operation of both Transmission and the Generator circuit breaker as shown in figure 4, again the Generator will be permitted to trip to clear the fault as detailed in the proposed new section CC.6.3.15(a)(i)(b)(ii) and ECC.6.3.15.8(vi)(i), as follows: -

the location of the fault means it cannot be fully cleared without tripping the of **Generating Unit**, **DC Converter**, or **Power Park Module** and any constituent **Power Park Unit** thereof and the **OTSDUW Plant** shall trip as required.

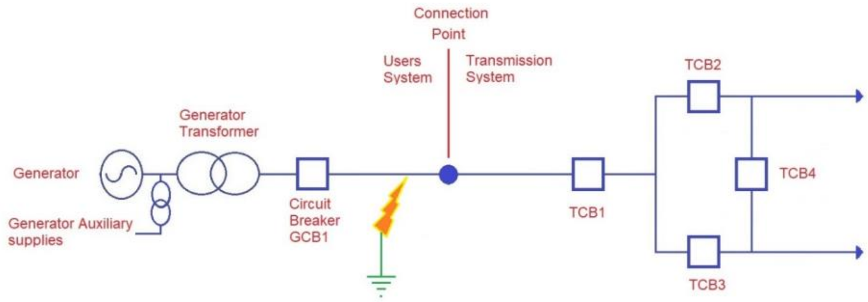


Figure 4 showing a fault which can only be cleared by generator breaker GCB1 & transmission circuit breaker TCB1

Thirdly, if the location of the fault on the network means that the Generator will become islanded by the operation of the transmission circuit breakers as shown in figure 5 then it shall be permitted to trip as detailed in the proposed new sections CC.6.3.15(a)(ii)(b)(iii) and ECC.6.3.15.8(vi)(ii), as follows: -

clearance of the fault results in the **Generating Unit**, **DC Converter**, or **Power Park Module** or **OTSDUW Plant** becoming islanded and disconnected from the **Total System** and not supplying **Customers** (where CC.6.3.7(c)(i) applies), then the **Generating Unit**, **DC Converter**, or **OTSDUW Plants** shall be permitted to trip as required.

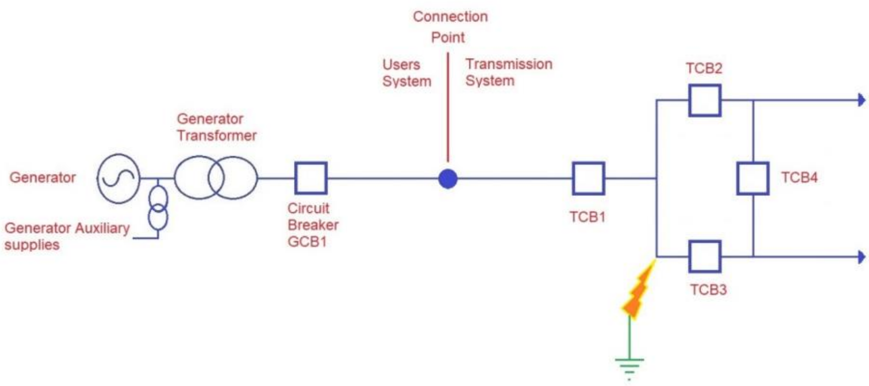


Figure 5 showing a fault which can be cleared by transmission breakers TCB1,2&3, however this results in the Generator being islanded from the main transmission system and needs to come off

Also, if there are inter-trip arrangements with the TO or ESO in relation to protection schemes to prevent cascade overloading, etc then plants shall be required to trip as per these arrangements as detailed in the proposed new section CC.6.3.15(a)(i)(b)(iv & v) and ECC.6.3.15.8(iii & iv),as follows:-

the **Generating Unit**, **DC Converter**, or **Power Park Module** and any constituent **Power Park Unit** thereof and **OTSDUW Plant** is part of combined protection scheme with the **Transmission Operator**, then the **Generating Unit**, **DC Converter**, or **Power Park Module** and any constituent **Power Park Unit** thereof and **OTSDUW Plants** shall be permitted to trip as required**.**

the **Generating Unit**, **DC Converter**, or **Power Park Module** and any constituent **Power Park Unit** thereof and **OTSDUW Plant** is part of and intertrip scheme which is switched into service and triggered, then the **Generating Unit**, **DC Converter**, or **Power Park Module** and any constituent **Power Park Unit** thereof and **OTSDUW Plants** shall be permitted to trip as required**.**

There is a final section on Offshore transmission which already exists and has just been moved as it relates to operational actions and is not a capability, this is basically the original text as detailed in section CC.6.3.15(a)(i)(b)(vi) (note there was no original text equivalent to this in the ECCs so it has not been added) as follows: -

in the case of an **Offshore Generating Unit**, **Offshore DC Converter** or **Offshore Power Park Module** (including any **Offshore Power Park Unit** thereof) which is connected to an **Offshore Transmission System** which includes a **Transmission DC Converter** as part of that **Offshore Transmission System**, the **Offshore Grid Entry Point** voltage may not indicate the presence of a fault on the **Onshore Transmission System**. The fault will affect the level of **Active Power** that can be transferred to the **Onshore Transmission System** and therefore subject the **Offshore Generating Unit**, **Offshore DC Converter** or **Offshore Power Park Module** (including any **Offshore Power Park Unit** thereof) to a load rejection

Fault Current Injection

The area of the current legal text which technically creates the biggest problem in relation to compliance are in sections CC.6.3.15 (a)(ii) and ECC.6.3.15.9.2.1(a)(i) which currently state "for which the voltage at the Grid Entry Point (or Interface Point in the case of OTSDUW Plant and Apparatus) is outside the limits specified in CC.6.1.4, each Generating Unit or Power Park Module or OTSDUW Plant and Apparatus shall generate maximum reactive current". If this requirement is drawn out on the figure 6 below where the current and voltage must always either be within the green shaded area or on the red line.

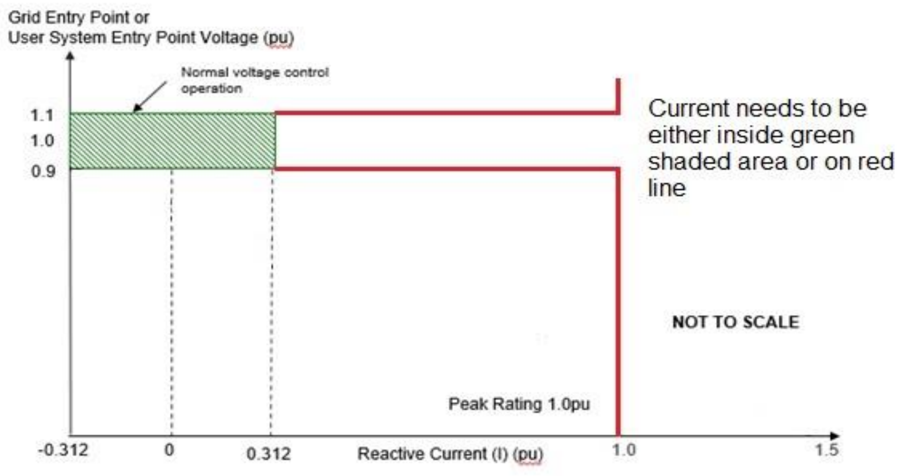


Figure 6 showing an interpretation of the existing legal text requiring the current to either be in the green box or on the red line

The reason this creates compliance issues is: as drafted, very few plants (if any) actually do this and it has presumably drifted in as a drafting oversight relating to PPM requirements. This issue has previously been identified in the workgroup GC0111 on Fast Fault Current injection and in the GC0137 VSM workgroup and has been fixed for new PPMs, however currently all synchronous Generator and older PPM will technically be non-compliant with this FRT requirement as drafted. This issue was dealt with in GC0111 by adding a new Figure ECC.6.3.16(a), however this is more onerous than is required for GB Users so the graph shown in figure 7 is proposed with text changes as follows: -

(iv) During the period of the fault as detailed in CC.6.3.15.1 (a) (i) for which the voltage at the **Grid Entry Point** (or **Interface Point** in the case of **OTSDUW Plant and Apparatus**) is outside the limits specified in CC.6.1.4, each **Generating Unit** or **Power Park Module** or **OTSDUW Plant and Apparatus** shall inject a reactive current above the heavy black line shown in Figure CC.6.3.15(b) without exceeding the transient rating limit of the **Generating Unit**, **OTSDUW Plant and Apparatus** or **Power Park Module** and / or any constituent **Power Park Unit** or reactive compensation equipment.

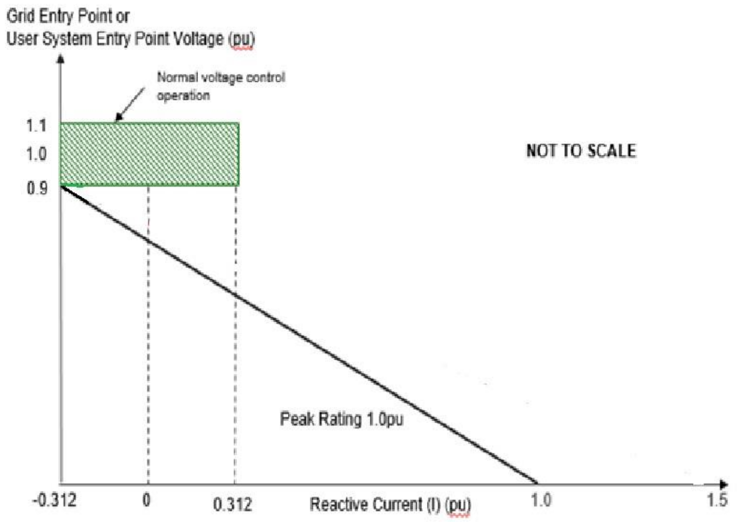


Figure 7 showing the proposed reactive current injection requirements, requiring the current to always remain above the black line

Active Power Requirements

The final area of concern is the minimum active Power requirements after the fault has cleared because within CC.6.3.15.1 a) ii) it states:

(or within 0.5 seconds of restoration of the voltage at the **User System Entry Point** to 90% of nominal or greater if **Embedded**), Active Power output or in the case of OTSDUW Plant and Apparatus, Active Power transfer capability, shall be restored to at least 90% of the level available immediately before the fault. Once the Active Power output, or in the case of OTSDUW Plant and Apparatus, Active Power transfer capability, has been restored to the required level, Active Power oscillations shall be acceptable provided that:

- the total Active Energy delivered during the period of the oscillations is at least that which would have been delivered if the Active Power was constant

- the oscillations are adequately damped

Whilst this works in principle at higher loads, it does create an issue at lower loads if you consider a real event for a unit operating as a synchronous condenser in figure 8.

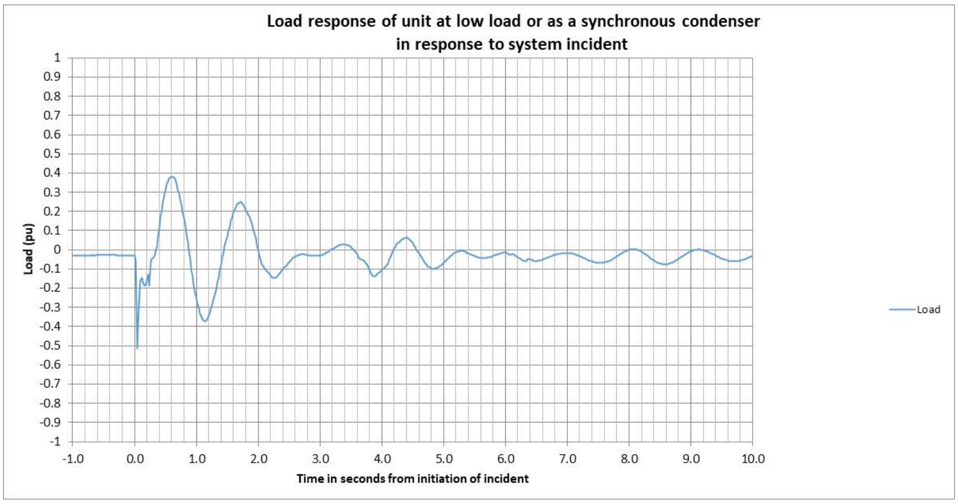


Figure 8 showing a typical active power response of a unit at low load to a fault

If you look at the initial load which is 0.02 pu then 90% of this small number you get a very small number, it is also difficult to see how a sensible compliance assessment can be carried out at these levels and it is hence suggested that under these circumstances the tolerance should be changed.

Voltage Protection Settings

The Original proposal for GC0151 included looking at the relationship between voltage and FRT criteria however no text was included in either the Original or WAGCM2 as it was deemed too difficult for the urgent time scale.

Whilst the Grid Code defines in detail the FRT requirements for voltage dips, it is silent on the need for Users or Network Operators to remain connected for transient over-voltages, particularly those that are expected to occur after the clearance of a fault. Therefore, it is possible, for example, that currently a Generator or Interconnector may successfully ride through a voltage dip, but trip when the fault is cleared as the resulting over-voltage transient is sufficiently high or sustained that it could trigger over-voltage protection that would ordinarily be expected to be fitted by the User (or Network Operator) to protect their equipment.

It is also possible a User site or Network Operator asset could ride through a low voltage fault but incorrectly configured protection settings result in the User site or Network Operator asset(s) tripping or de-loading.

To provide further clarity to Users and Network Operators, it is proposed that wording along the following lines would be added to Section CC.6.3.15.3 and ECC.6.3.15.10 ('Other Fault Ride Through Requirements'):

- Users and Network Operators shall ensure voltage sensitive relays installed to protect the User's plant and / or apparatus or Network Operator's asset are configured such that they will not prevent correct operation of the Fault-Ride-Through capability of the User's equipment (or Network Operator's assets) against the relevant Voltage-Time curves. For example,

    o Over-voltage protection shall be configured to be insensitive to transient overvoltages of at least 1.20pu for at least 0.5 seconds.

    o Under-voltage protection shall be configured to be insensitive for transient undervoltages of below 0.8pu for at least 3 seconds

Workgroup considerations

The Workgroup convened XX 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 Code Objectives. The Workgroup were well represented with various industry experts and in some cases other stakeholders were consulted by the ESO as required.

Clarification of requirements for over-voltage during a fault

The Proposer confirmed that the current expectation is that systems will be designed in accordance to the definition in TGN288. The ESO representative acknowledged that there is no requirement for compliance for over voltage in the Grid Code but, there is provision for compliance to outages.

There were mixed views as to whether the overvoltage requirement if considered within this modification, should apply retrospectively. Some Workgroup members suggested that this will raise an element of cost and would need to be considered in detail and decided by the ESO. However, it was highlighted that concerns about costs do not only apply where the requirements are retrospective because overvoltage ride through requirements would bring about significant cost of new equipment especially if the requirements are oneorous.

Some Workgroup members suggested that a comparison with other international standards (and commercially available equipment) could help minimise over or under specifying requirements impacting cost and security of supply respectively. This international comparison should not just be waiting for a new, as yet unpublished standard from ENTSO–E which may not fit with the timescale of this modification but, it could form part of the justification for limits proposed within any future strawman.

Phase Angle Jumps and Short Circuit Level

The topic of phase angle jumps was raised specifically with respect to Phased Locked Loop fault ride through capability. A Workgroup member shared the table below, an example given was of large phase angle jumps in Scotland being caused by transmission network faults in North Wales, showing that this is already a problem in the GB grid as Generators with PLL are not designed for these conditions and this could lead to Generators' tripping. Although it was discussed that there are no specified FRT requirements for phase angle jumps but, whilst the ESO expressed support for these requirements, it was clearly stated that this subject area was outside of scope and would not be considered within the requirements of this modification.

Table 1.1: Causes of Reduction

Cause of Reduction	Reduction [MW]
PLL Loss of Synchronism	389
Inverter AC Overvoltage	269
Momentary Cessation	153
Feeder AC Overvoltage	147
Unknown	51
Inverter Underfrequency	48
Not Analyzed	34
Feeder Underfrequency	21

* See explanation below.

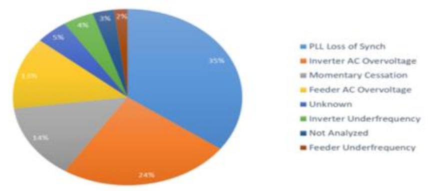


Figure 1.1: Causes of Solar PV Reduction

NERC | Odessa Disturbance Report | September 2021

A Workgroup member suggested that if these topics of phase steps and SCL are not to be considered with this modification it should be decided whether it would be addressed in later modifications, or whether these issues posed such low risk that they could be safely ignored. The ESO representative requested that, to better understand the issues and identify whether needed to be addressed or investigated further, the Workgroup members should share examples of issues caused by sudden changes in phase angles; how they affect the control systems and any implications associated with retuning these control systems.

Multiple Fault Ride Through Scenarios

Some Workgroup members raised concerns over lack of clear requirements in the case of multiple FRTs. This had been highlighted as a concern due to incidents that occurred in other countries. The ESO representative advised that, following a review, it was established that it would be highly unlikely that this would occur in the UK due to the weather conditions. It was therefore noted that as multiple FRT currently has a low needs case, the ESO is not looking to progress it within this modification.

ENTSO-E High Voltage Ride Through (HVRT) Requirements

It was mentioned that ENTSO-E are looking at entering HVRT requirements into the Requirement for Generators (RfG). This would be consider creating thresholds for duration and voltage level. The ESO representative confirmed that the ESO are no longer members of ENTSO-E and have no visibility of the draft document in relation to this but advised that the ENTSO-E document should be published sometime in 2023 and once published, the ESO will review the document and determine elements that need to be added into the Codes.

Amendments to the Draft Legal Text

The following amendments were made to the initial draft following workgroup deliberations:

Graph removed and modified text for sections CC.6.3.15a(iii) as shown below:

*"(iii) During the period of the fault as detailed in CC.6.3.15.1 (a) (i)(a) for which the voltage at the **Grid Entry Point** (or **Interface Point** in the case of **OTSDUW Plant and Apparatus**) is zero volts ~~outside the limits specified in CC.6.1.4~~, each **Generating Unit** or **Power Park Module** or **OTSDUW Plant and Apparatus** shall generate maximum reactive current without exceeding the transient rating limit of the **Generating Unit**, **OTSDUW Plant and Apparatus** or **Power Park Module** and / or any constituent **Power Park Unit** or reactive compensation equipment."*

It was noted that in the original H04 modification the text *"is outside the limits specified in CC.6.1.4"* did not exist and appears to have been added for clarification only, however, the fault described in CC.6.3.15.1 is a hard 140ms 0volt fault so there are no other voltages therefore replacing with "zero volts" better describes the actual situation.

Graph removed and modified text for sections CC.6.3.15.1 1b(ii), CC.6.3.15.1 2b(ii), CC.6.3.15.2 a(ii), CC.6.3.15.2 1b(ii), CC.6.3.15.2 2b(ii), & ECC.6.3.15.9.2.1a(ii) as shown below:

*"(ii) provide **Active Power** output at the **Grid Entry Point**, during **Supergrid Voltage** dips on the **Onshore Transmission System** as described in Figure 5a, at least in proportion to the retained balanced voltage at the **Onshore Grid Entry Point** (for **Onshore Synchronous Generating Units)** or **Interface Point** (for **Offshore Synchronous Generating Units)** (or the retained balanced voltage at the **User System Entry Point** if **Embedded**) and shall correspondingly generate proportionate ~~maximum~~ reactive current (where the voltage at the **Grid Entry Point** is outside the limits specified in CC.6.1.4) without exceeding the transient rating limits of the **Synchronous Generating Unit** and ….."*

Note: This change above would affect the graph depicted in figure 7 within the "Proposer's Solution" section above.

Implementation Costs

…….If the Overvoltage compliance requirements will not be considered within this modification, there are no associated implementation costs.

Operating Requirements during a fault

The Proposer highlighted concerns that the current text could be interpreted that the plant should remain connected feeding the fault for 140ms which could lead to dangerous outcomes. But, the intention is that plant should trip during these circumstances hence, it was proposed that 3 subclauses should be added to section CC.6.3.15(a) to clarify each situation where tripping is permitted. This was agreed by the Workgroup.

Expectations to clear transmissions system faults

The instances where User plant is required to trip in order to clear transmission system faults were clarified in section CC.6.3.15(a)(i)(a) of the legal text available in Annex 3.

Commented [JOB3]: Check with TB

Maximum Reactive Current during faults & Short Circuit Levels (SCL)

The proposed requirements for generating maximum reactive current during faults were agreed and are documented in sec xxxxxx of the legal text available in Annex 3. A Workgroup member highlighted concerns around Transient Overvoltage stating that during fault clearance through to the transient state where the voltage is recovering to its steady state value, there are significant voltage oscillations before the voltage settles back down. Another Workgroup member stated that to tackle this, the ESO may need to refine the requirements of reactive current injection within that recovery time along with defining the minimum SCL required to allow Users connect at certain megawatt ratings.

The ESO representative acknowledged that there is an issue with decreasing SCL and that whilst it may impact achieving the clarifications identified within this modification, it is a much bigger piece of work than the scope of this modification and was being assessed within a System Operability Framework (SOF). It was noted that the SOF had published a paper to discuss the current and future requirements for SCL data and was seeking feedback from stakeholders on this topic including whether a minimum SCL needs to be defined. The ESO representative advised the Workgroup that if the need for Grid Code changes are identified a new Grid Code modification would be raised to address them.

The ESO representative highlighted interactions with Frequency Management and explained that reactive current injection during a fault supports the system voltage and contributes towards rapid voltage recovery. This reduces the risk of further generation tripping and changes to this could increase simultaneous tripping of generation (low frequency demand disconnection). This last occurred on 9 August 2019 and had significant repercussions. The ESO would find it very difficult to manage this risk as they would either have to:

a) Carry out further EMT simulations – which they do not have the resource or time to do.
b) Set a low limit and procure frequency response to manage the risk – which would cost too much.

Post-active fault power requirements

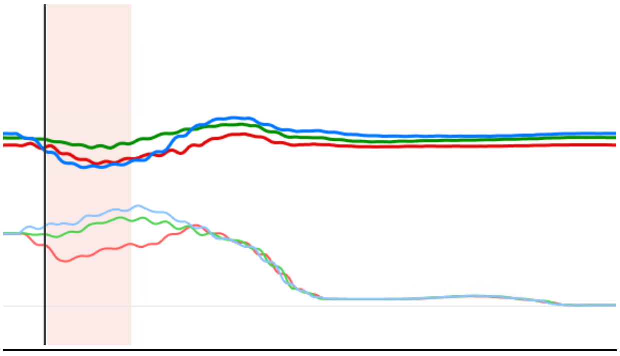
There was an initial discussion on post-fault active power requirements and consideration as to whether Generators at low load may have greater levels of oscillation than permitted and, it was noted that ……………………………

SSE HVRT Strawman

A workgroup member presented a strawman (available in annex 2) in relation to HVRT and outlined the following points for discussion:

Weaker Grids Transient Stability Issues: Background

- During a fault ride-through event, a transient over-voltage often develops on fault recovery which can often exceed 1.10pu – particularly in weaker grids.
- Phase angle jump on fault recovery due to weak grid conditions: existing users should not be penalised for not being able to ride through large phase jumps, as this was not an original requirement.
- Lack of detail in the GB Grid Code on appropriate overvoltage generator protection settings.
    - ENA Standard G99 contains some guidance for over-voltage protection settings for Generators connected to the distribution system and introduces a delay to 'avoid nuisance tripping for short duration excursions'
- The intention of GC0155 is to clarify what *minimum* over-voltage protection settings should be applied by Users, irrespective of connection voltage, in particular to avoid WTG tripping following a low-voltage FRT event.



High-Voltage Ride Through: 'Strawman' Proposal

- Proposed technical strawman is as shown opposite, based on different Grid Codes. However, it should be NGESO's operational requirements that should be setting the final HVRT requirements.
- **Forward-looking only:**
    - WG consultation to ask about practicality of retrospective changes to HV settings.
    - Confirm if HVRT requirements will be applied across GB and if so confirm whether HVRT requirements set out in BCAs (for connections in England & Wales) would be updated.
- HVRT requirements to apply at the point of connection, rather than at the HV terminals of User's plant/equipment.
- Requirement for repeatability of response to be defined (also required for Low-Voltage Ride-Through requirements).

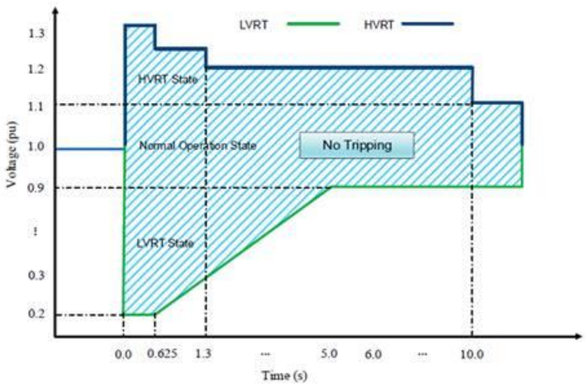


Figure 1. An example of fault ride-through (FRT) grid codes.

The mainstream grid codes for FRT from different nations are listed and compared in Table 1 [19–25]. It is shown that, for LVRT, zero voltage ride-through (ZVRT) is also essential in most of the grid codes. On the other hand, for HVRT, it is required that the WTG should stay interconnected when the grid voltage is within [1.10, 1.30] pu by most of the grid codes. Under different undervoltage and overvoltage conditions, WTGs are required to stay connected from milliseconds to seconds.

Table 1. Comparison of grid codes around the world.

Nation	Maximum Voltage Dip	Maximum Dip Duration	Maximum Voltage Swell	Maximum Swell Duration
Denmark Energinet	0.2 pu	0.5 s	1.30 pu	0.1 s
Germany VDE FNN	0.0 pu	0.15 s	1.25 pu	0.1 s
America WECC	0.0 pu	0.15 s	1.20 pu	1 s
Australia AEMC	0.0 pu	0.12 s	1.30 pu	0.2 s
China SAC	0.2 pu	0.625 s	1.30 pu	0.5 s

The Workgroup discussed these points and concluded that this strawman should be considered by the ESO. They requested that the ESO take away the following questions and provide feedback:

- Clarity on how User's plant/equipment should respond during over-voltage transient e.g. reactive power set point could vary upon reaching 1.0pu during recovery
- What happens with TGN 288 if HVRT requirements are included in the Grid Code
- Whether WTG manufacturers need to carry out type tests or just simulations to demonstrate HVRT compliance
- Currently there is set of scenarios for FRT simulations (refer to ECP.A.3.5), what would be the set of scenarios for HVRT simulations?
- What types of faults HVRT definition will apply to (e.g. single phase, phase to phase, etc); is it is a TGN 288 requirement that only aims to define overvoltage withstand capabilities of the plant or a requirement during fault clearance only
- The requirement shall be technology neutral, so what will the HVRT requirement be for synchronous plant?

The ESO's response to the above strawman and the discussions on it was that whilst the ESO recognised that the overvoltage requirements in the Grid Code on generators following a fault are not clear and require further guidance, overvoltage is also addressed in TGN288 and setting out the right Grid Code details is likely to mean considering both these and the relationships between system security and consumer value. The ESO therefore proposes that, to be able to properly assess this requirement it would be best to progress this it via a separate Grid Code modification rather than within GC0155 which was intended to agree on reasonably straightforward clarifications to the technical detail of

FRT requirements. This will enable the ESO to allocate resources to fully scrutinise the issue, assess potential solutions and consult with industry.

Following the ESO response, some Workgroup members (from SSE, Drax and Scottish Power) expressed that the high-voltage ride through requirements should be clarified for users as part of this modification. They developed a draft legal text which was discussed with the rest of the Workgroup. Their proposal – which requires an EU Generator to ride through 1.3pu for 0.1s and 1.25pu for 60s was based on an extract from the German Grid Code and their rationale is outlined below:

- The requirement would be applicable to all EU Generators. The exact numbers, wording, and graphical representation were to be decided.
- The fact that the high voltage transient typically occurs immediately following fault clearance has been accounted for in the voltage-against-time graphs by using equations for ‘tov1’ and ‘tov2’, such that they depend on the time at which fault clearance occurs. For high voltage transient faults which do not have a preceding low-voltage element, the requirement applies from the instant the voltage exceeds normal limits.
- The proposal will apply on a forward-looking basis only. A comprehensive check of the over-voltage ride through capabilities of those WTG models which must adhere to the ECCs is still ongoing, but at present our understanding is that 1.3pu for 0.1s and 1.25pu for 60s is easily achievable.
- It would be beneficial (for all parties) to have clarity on the HVRT requirements, but, any equivalent addition to the CCs on a retrospective basis ought to be set at a level which does not then necessitate further action, i.e. the HVRT requirement should be based on the existing HVRT capability.

Commented [JOB4]: FN suggested that a consultation question could be drafted to confirm this.

Commented [JOB5]: FN suggested that a consultation question could be drafted to gather feedback on what the existing high voltage ride through / high voltage withstand capability is.

ESO proposed approach to address Temporary Overvoltage Requirements

The ESO and NGET Workgroup members explained to the rest of the Workgroup how they propose to set the expected TOV level using TGN 288 (which was presented at a previous Workgroup) as a starting point. proposed that the Workgroup considered these two steps when setting requirements for FRT:

1) TOV withstand capability of equipment; and
2) Power Electronic (PE) equipment performance during and after an event.
It was also suggested that the Grid Code definition of earth fault factor should be considered when establishing these requirements.

The ESO representative explained that a significant drop in voltage means that a Generating Unit will not be able to deliver its full output for that period. This is because the mechanical input for the Generating Unit is unlikely to change fast enough so the power imbalance will cause the rotor of a synchronous machine to accelerate, as well as a rise within the DC link voltage within a wind turbine. If this persists for a long period of time, the low voltage is likely to cause pole slipping for synchronous machines and excessive heating for the DC link chopper resistor. Currently, there are no limits on high voltages within the Grid Code and Users were required to ride through any faults above the black line within the diagram below.

It was decided that the following steps will be taken to define overvoltage requirements:

- Define a ceiling for TOV which would have to be guaranteed by design by the Transmission Owners (TO’s) for the network. There would also be a requirement on generators not to cause it to exceed those values. The ESO preference is to use the limits already available within TGN 288 as the ceiling, as this is consistently used by all the TO's and should also be the minimum capability of Users' plant.

- Review other related plant performance and FRT requirements to understand how the plant is going to respond to TOV and not exacerbate any such an event.

A Workgroup member noted that these requirements had not been included in any previous grid compliance simulations, so they were already in a situation where it is unclear what the HVRT capability of the equipment installed to date is. Therefore, the ESO may still need to procure some frequency response reserve in case there is tripping within these overvoltage limits. The Workgroup member also suggested a more pragmatic approach to address the capability of equipment installed to date and future plant installations separately.

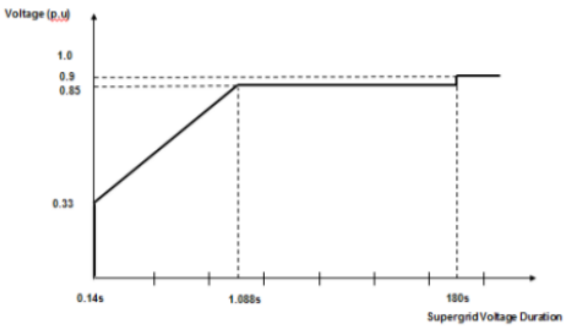


Figure 5a

Some of the comments from Workgroup members were:

- On the query as to whether the withstand capability implies ride through, the ESO and NGET representative clarified that the expectation is that the equipment will need to have design and performance capability to withstand and ride through faults - the problem had been categorised in two parts.
- In relation to challenges posed by high voltage FRT and capability at the point of connection, several Workgroup members questioned whether the ESO had carried out simulations for high voltage FRT as part of their Grid Code compliance checks before allowing parties to connect. They felt that parties should have been informed at that stage that their equipment was non-compliant, rather than permitting them to connect and then expecting them to ride though.
- The earth fault factor would need to be considered future simulations. There is a physical limit to design constraint; Silicon Convertors are more sensitive to over voltage than other devices in high voltage networks. Thus, to make them more robust the ESO would need to design for that and explore the relationship between high voltage tolerance over specific periods of time.
- During a HVRT, there is a reverse power flow from the Grid to the DC link, which causes a stress on it. This can only be tuned and managed to a certain degree, beyond which there is a threat to the wind turbine which causes it to De-load. They advised that it is globally acknowledged that

there is an upper limit, beyond which parties should be allowed to trip, and from assessment this is currently 1.3 pu.

WAGCM1 Outline

Cross code impacts

The Workgroup considered whether there were potential impacts on the G99 requirements and it was noted that there were no consequential impact.

Commented [JOB6]: Update as required
As overvoltage compliance is now being considered within this modification there may be cross code impacts.

Workgroup consultation question: Xxxxx?

Draft legal text

The draft legal text created as part of GC0151 WAGCM2 Alternative Proposal Legal Text has been further developed and is available in Annex 3.

What is the impact of this change?

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	**Positive** By improving Generator confidence in their ability to comply with FRT requirements and lessening the likelihood of compliance proceedings including following an incident where a Generator has tripped for allowable reasons.
(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);	**Neutral** [Please provide your rationale]
(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** By providing clearer guidance on expected behaviour following a fault, Generators are able to prepare more effectively and be more resilient as a

	result so improving system security.
(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** [Please provide your rationale]
(e) To promote efficiency in the implementation and administration of the Grid Code arrangements	**Positive** By improving clarity in FRT requirements this will help to improve efficiency.

Proposer's assessment of the impact of the modification on the stakeholder / consumer benefit categories	
Stakeholder / consumer benefit categories	**Identified impact**
Improved safety and reliability of the system	**Positive** This change should improve compliance to FRT as the obligations will be clearer meaning a more stable system during fault conditions.
Lower bills than would otherwise be the case	**Positive** By reducing non-conformities this should reduce the need to constrain Generators following a fault.
Benefits for society as a whole	**Positive** Reducing tripping will provide a more stable network ensuring security of supply.
Reduced environmental damage	**Neutral** No Impact
Improved quality of service	**Positive** Providing clearer guidance to new and existing connections on their obligations.

Standard Workgroup consultation question: Do you believe that GC0155 Original proposal better facilitates the Applicable Objectives?

When will this change take place?

Implementation date
10 days after authority approval.

Date decision required by
The decision is required from the Authority as soon as reasonably practicable

Implementation approach
The implementation approach will depend on the level of change required by industry following clarifications provided by the workgroup.

Interactions

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

How to respond

The Workgroup is seeking the views of Grid Code Users and other interested parties in relation to the issues noted in this document and specifically in response to the questions above.
Please send your response to grid.code@nationalgrideso.com using the response pro-forma which can be found on the GC0155 modification page.
In accordance with Governance Rules if you wish to raise a Workgroup Consultation Alternative Request please fill in the form which you can find at the above link.

If you wish to submit a confidential response, mark the relevant box on your consultation proforma. Confidential responses will be disclosed to the Authority in full but, unless agreed otherwise, will not be shared with the Panel, Workgroup or the industry and may therefore not influence the debate to the same extent as a non-confidential response.

Standard Workgroup consultation questions

1. Do you believe that GC0155 Original proposal better facilitates the Applicable Objectives?
2. Do you support the proposed implementation approach?
3. Do you have any other comments?
4. Do you wish to raise a Workgroup Consultation Alternative request for the Workgroup to consider?

Specific Workgroup consultation questions

5. Xxxxxxxx

[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.

Acronyms, key terms and reference material

Acronym / key term	Meaning
BSC	Balancing and Settlement Code
CC	Connection Conditions
CP	Compliance Process
CUSC	Connection and Use of System Code
EBR	Electricity Balancing Regulation
ECP	European Compliance Process
FRT	Fault Ride Through
GC	Grid Code
NGESO	National Grid Electricity System Operator
PLL	Phase Lock(ed) Loop
RfG	Request for Generators
SCL	Short Circuit Levels
SOF	System Operability Framework
STC	System Operator Transmission Owner Code
SQSS	Security and Quality of Supply Standards
T&Cs	Terms and Conditions
TO	Transmission Owner

Reference material

- GC0151
- OFGEM Decision

Annexes

Commented [JOB7]: Consider including AL's write up

Annex	Information
Annex 1	Proposal form
Annex 2	SSE HVRT Strawman
Annex 3	Draft legal text
Annex X	
Annex X	
Annex X	
Annex X	