Disclaimer
This document is a work in progress, and has not been updated to reflect the changes made to the RFG Network Code once it was resubmitted to ACER in March.

Date:-1 March 2013

IMPLEMENTATION OF ENTSO-E REQUIREMENTS FOR GENERATORS (RfG) INTO THE GB GRID CODE

Executive Summary

During the last few months National Grid together with Distribution Network Operator representatives and Ofgem have been considering options for the implementing the ENTSO-E Requirements for Generators into the GB Code.

The purpose of this paper is to detail the options considered going forward with a view to suggesting a practical method for implementing the RfG Code into the GB Grid Code whilst also providing some thoughts as to how the other European codes could also be implemented into the GB Grid Code.

In summary, National Grid in collaboration with the DNO's and Ofgem propose that so far as the Grid Code is concerned, the structure of the Grid Code should remain more or less as it is and the individual technical elements are then updated to align with the specific elements of the ENTSO-E RfG Code. In this way, the non cross border elements in the GB Code can be retained and the new elements can be inserted enabling an auditable process to be followed in transitioning to the new code. In other words the GB Grid Code would require a fundamental review but should at least retain its overall structure.

The intention of National Grid, the DNO's and Ofgem in developing an appropriate implementation strategy hinges on the key criertia.

- All Codes (G Code / D Code) to be fully consistent with the requirements of the ENTSO-E RfG
- In the best interests of all Stakeholders (Generators, DNO's, Transmission Owners and System Operators)
- Minimise the number of Industry Codes that each party is required to access.
- Ensure contractual arrangements between appropriate parties is in place.

The ENTSO-E RfG has graded requirements Types A – D (Type A 800W – 1MW, Type B 1MW – 10MW, Type C 10MW – 30 MW connected below 110kV and Type D 30MW or above or connected at 110kV or above) where as the GB Grid Code deals only with Large, Medium and Small Power Stations. Since the majority of connections that National Grid deal with are generally in excess of 30MW and having worked through a number of detailed examples, it is considered appropriate that the Type A – C Generator Requirements should be placed in the Distribution Code / appropriate Engineering Recommendations (eg G83 and G59/2) and the Type D Generator requirements placed in the Grid Code. In this way the contractual relationship for Type A – C Generators would rest with the DNO and those for Type D Generators would lie with National Grid, allowing for the fact there would need to be closer liaison between National Grid and the DNO's for managing the higher volumes of Embedded Generation in the future. A further complexity is the difference in the terms and definitions between the ENTSO-E and GB Grid Code though in practice it is expected a mix of the two will be required.

In establishing this approach, National Grid has used a number of detailed examples, (Voltage Range, Frequency Range, Black Start and Fault Ride Through) to test if such an approach will work and it is believed the work to date and the suggested approach is worth further examination. Notwithstanding this, National Grid and the DNO's welcome the opportunity to discuss this approach with stakeholders through the JESG to seek their views

and comments before committing to further implementation work, whilst recognising that such discussions should concentrate on the high level approach and principles rather than text associated with any specific example.

Scope

The high level options for implementing the ENTSO-E RfG into the GB Grid Code have been presented in a paper prepared by Cameron Mckenna LLP with input from National Grid [1]. This paper was discussed between National Grid, Ofgem and Distribution Network Operators on the 1st October with the conclusion being reached that Option 1 (ie keep the GB Grid Code more or less as is which would apply to existing Generators) and amend the existing GB Code to align with the European Network Code Requirements for Generators) or Option 4 re-write the GB Code.

For the purposes of this paper, it is acknowledged that special provisions will need to adopted to define the requirements at existing sites, either through the retention of the current GB Grid Code in some form, or by amendments to the current Bilateral Connection Agreements (BCA's). For the time being however, consideration needs to be given to the longer term enduring arrangements for new Generators who seek to connect to the National Electricity Transmission System under the European framework.

This paper therefore builds on the approach suggested under options 1 and 4 in [1] and concludes with a number of examples of how these approaches could be adopted. At this stage, it is envisaged that Option 4 (rewrite the Grid Code) may be a better approach as option 1 (retain existing code) and develop a new code would largely converge (in the longer term) to the same point although this approach is favoured for dealing with existing classes of Generator.

Development of Option 4

It is acknowledged that the structure of the GB Grid Code is very different to that of the ENTSO-E Network Code Requirements for Generators. To this end, it is worth considering the structure of the two documents with a view to formulating a common approach, prior to engaging in detailed drafting.

When the European Network Codes are implemented, the intention will be for the National Codes to interface with the European Code, such that the European Code provides the overall guiding requirements and principles with the National Codes detailing the full technical requirements and being consistent with the European Code. It should also be recalled that the GB Grid Code covers a wide range of non cross border issues unlike the Network Code Requirements for Generators which largely only covers the connection conditions pertaining to Generators. Not withstanding this, and noting that the ENTSO-E RfG is the first of the European Codes to be developed, any approach for implementing the two codes will need to be mindful of the subsequent codes which are introduced at a later date. Figure 1 below provides an indication of the overall structure between the European Codes and National Codes. To put this in perspective, a number of other codes have been included within the diagram to give an indication of how they will interface with the National Codes.

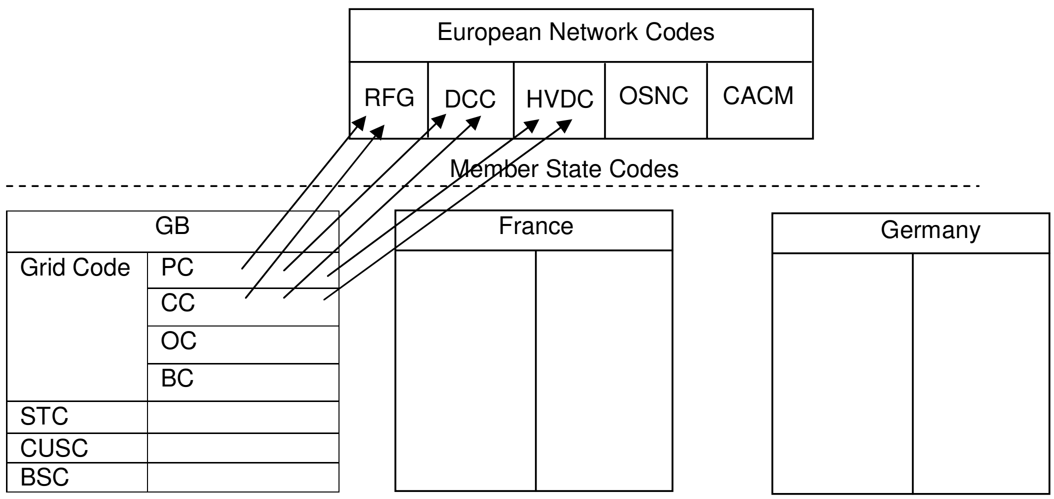

Figure 1

Figure 2 and Table 1 below shows the differences in general structure between the GB Grid Code and ENTSO Requirements for Generators.

GB Code	ENTSO-E RfG
Specifies technical requirement and the types of Generator to which the requirement applies Captures Large, Medium and Small Power Stations but generally from 10MW and above in Scotland recognising Regional differences	Specifies type of Generator and the technical requirements applying to them Captures Types A (800W – 1MW), B (1MW – 10MW), C (10MW – 30MW) and D (30MW+ or connected at 110KV or above)

Figure 2

GB Grid Code		ENTSO-E RfG	
Specifies each ***Connection Requirement*** and then how that requirement applies to each type of Generator technology.		Specifies what Connection requirements applies to each ***Specific Type of Generator*** based on ***Size*** and ***Connection Voltage***.	
Eg CC.6.3.2 (Reactive Capability)		Eg Article 8 General Requirements on Type A Power Generating Modules	
CC.6.3.2(a)	Reactive Capability requirements for Synchronous Generating Units including Reactive Capability and Short	Article 8 (a)	Frequency Range

	Circuit Ratio.		
CC.6.3.2(b)	Reactive Capability requirements for Onshore Current Source HVDC, Onshore Non Synchronous Generating Units and Onshore Power Park Modules	Article 8 (b)	Rate of change of Frequency
CC.6.3.2(c)	Reactive Capability requirements for Onshore Power Park Modules, Onshore DC Converters (excluding Current Source Converters) with a Completion Date after 1 January 2006	Article 8 (c)	Provision of Limited Frequency Sensitive Mode – Over Frequency
CC.6.3.2(d)	Reactive Capability requirements for Generating Units and Onshore Power Park Modules in Scotland with a Completion Date after 1 April 2005 and before 1 January 2006.	Article 8 (d)	Provision of Output Power with Falling Frequency
CC.6.3.2(e)	Reactive Capability requirements for Offshore Synchronous Generating Units, Offshore Non Synchronous Generating Units and Offshore DC Converters	Article 8(f)	Requirement for Type A Generators to be fitted with a logic interface to cease output within less than 5 seconds.
		Article 8(g)	Conditions as required by the TSO for Type A Generators to reconnect to the System.

Table 1

As a general rule, the RfG tends to concentrate on cross border issues and high level principles whereas the GB Grid Code will always concentrate on the more detailed requirements, many of which are not of a cross border nature.

With the introduction of the European Network Codes, the National Codes will always refer to the European code. Noting that much of the detail will not be included in the European Code, it is considered that the best way forward is to keep the structure of the GB Codes (Grid Code and Distribution Code) more or less as they are and then amend each specific clause as necessary to align with the European Code as shown in Table 2 below.

GB Grid Code Clause	
CC.6.3.2 – Reactive Capability	ENTSO-E / RfG Requirement covering all Generation technologies (Power Generating Modules, Synchronous Power Generating Modules and Power Park Modules) plus all GB defined requirements. Type A – C requirements covered in the Distribution Code and associated Engineering Recommendations.
CC.6.3.3 – Power Output with Falling Frequency	ENTSO-E / RfG Requirement covering all Generation technologies (Power Generating Modules, Synchronous Power Generating Modules and Power Park Modules) plus all GB defined requirements. Type A – C requirements covered in the Distribution Code and associated Engineering Recommendations.

CC.6.3.4 – Ability to supply Reactive Power over varying HV voltage ranges	ENTSO-E / RfG Requirement covering all Generation technologies (Power Generating Modules, Synchronous Power Generating Modules and Power Park Modules) plus all GB defined requirements. Type A – C requirements covered in the Distribution Code and associated Engineering Recommendations.
CC.6.3.5 – Black Start	ENTSO-E / RfG Requirement covering all Generation technologies (Power Generating Modules, Synchronous Power Generating Modules and Power Park Modules) plus all GB defined requirements. Type A – C requirements covered in the Distribution Code and associated Engineering Recommendations.
CC.6.3.6 – Ability to modulate Real and Reactive Power	ENTSO-E / RfG Requirement covering all Generation technologies (Power Generating Modules, Synchronous Power Generating Modules and Power Park Modules) plus all GB defined requirements. Type A – C requirements covered in the Distribution Code and associated Engineering Recommendations.
CC.6.3.7 – Frequency Control	ENTSO-E / RfG Requirement covering all Generation technologies (Power Generating Modules, Synchronous Power Generating Modules and Power Park Modules) plus all GB defined requirements. Type A – C requirements covered in the Distribution Code and associated Engineering Recommendations.
CC.6.3.8 – Excitation and Voltage Control	ENTSO-E / RfG Requirement covering all Generation technologies (Power Generating Modules, Synchronous Power Generating Modules and Power Park Modules) plus all GB defined requirements. Type A – C requirements covered in the Distribution Code and associated Engineering Recommendations.
CC.6.3.9 – Steady State load inaccuracies	ENTSO-E / RfG Requirement covering all Generation technologies (Power Generating Modules, Synchronous Power Generating Modules and Power Park Modules) plus all GB defined requirements. Type A – C requirements covered in the Distribution Code and associated Engineering Recommendations.
CC.6.3.10 – Negative Phase Sequence loadings	ENTSO-E / RfG Requirement covering all Generation technologies (Power Generating Modules, Synchronous Power Generating Modules and Power Park Modules) plus all GB defined requirements. Type A – C requirements covered in the Distribution Code and associated Engineering Recommendations.
CC.6.3.11 – Neutral Earthing	ENTSO-E / RfG Requirement covering all Generation technologies (Power Generating Modules, Synchronous Power Generating Modules and Power Park Modules) plus all GB defined requirements. Type A – C requirements covered in the Distribution Code and associated Engineering Recommendations.
CC.6.3.12 / CC.6.3.13 – Frequency Sensitive Relays	ENTSO-E / RfG Requirement covering all Generation technologies (Power Generating Modules, Synchronous Power Generating Modules and Power Park Modules) plus all GB

	defined requirements. Type A – C requirements covered in the Distribution Code and associated Engineering Recommendations.
CC.6.3.14 – Fast Start Capability	ENTSO-E / RfG Requirement covering all Generation technologies (Power Generating Modules, Synchronous Power Generating Modules and Power Park Modules) plus all GB defined requirements. Type A – C requirements covered in the Distribution Code and associated Engineering Recommendations.
CC.6.3.15 – Fault Ride Through	ENTSO-E / RfG Requirement covering all Generation technologies (Power Generating Modules, Synchronous Power Generating Modules and Power Park Modules) plus all GB defined requirements. Type A – C requirements covered in the Distribution Code and associated Engineering Recommendations.

Table 2

The advantage of this approach is that as the GB Codes are more detailed documents whereas the ENTSO-E Network Codes are more modular in their nature (ie RfG, HVDC Code, Demand Connection Code). This approach should enable the European requirements to be slotted into the GB Codes.

The complexity with this approach is that the structure of the ENTSO-E – RfG is very different from the GB Code in its treatment of Power Stations. Under the RfG, classification is based on the general requirements applicable to all types of Generating Plant (Power Generating Modules) and then further subdivided into threshold ie Type A, B, C and D. The requirements applicable to Type A units also apply to Types B, C and D and equivalently the requirements that apply to Type B also apply to Types C and D. The specific requirements applicable to Synchronous Generating Units (Synchronous Power Generating Modules) is then covered with the same requirements applicable to type A Synchronous Power Generating Modules applying to Types B, C and D. Equally the same approach is also adopted for Power Park Modules.

So far as the Grid Code is concerned this will require some quite detailed drafting in respect of Type D Power Generating Modules resulting in some overlap with the Type A – C requirements specified in the Distribution Code / Engineering Recommendations. However in view of simplifying the requirements to stakeholders this is not considered a major issue.

Conclusions

In the approach suggested above, the non cross border issues are retained in the National Codes (GB Grid Code and Distribution Code) whilst the cross border issues are amended in line with the European Code. There would of course need to be some amendments to the Glossary and Definitions but it is expected these would comprise a mix of the current GB Grid Code, Distribution Code and ENTSO-E RfG.

Five simple examples of how this approach may work are detailed in Appendix A of this document. The initial view adopted was that all the requirements (ie Types A – D) would be specified in the GB Grid Code and it is on this basis how the examples have been prepared. However, having considered the options and discussions with the DNO representatives it has subsequently been agreed that a better way forward would be to place the A – C requirements in the Distribution Code and the Type D requirements in the Grid Code.

Of the five simple examples prepared, fault ride through has been used as a complex example and this is illustrated in Appendix B. Again the example prepared has been developed on the basis that the GB Grid Code drafting applies to all Type A – D Power Generating Modules and not just Type D Power Generating Modules as is now being proposed with the Type A – C requirements being specified through the Distribution Code and associated Engineering Recommendations such as G59/2 and G83.

JESG members are requested to consider the approach presented in this paper and comment on the proposal. It is however emphasised that in order to develop these proposals further comments are requested in terms of the approach and not in respect of the drafting associated with the detailed examples.

References

[1] – National Grid / Cameron Mckenna ENTSO-E ERfG / GB Grid Code implementation options paper.

APPENDIX A

This Appendix provides a number of examples of how specific clauses in the ENTSO-E RfG could be integrated into the GB Grid Code Connection Conditions.

Example 1 – Frequency Range CC.6.1.32 and CC.6.1.3

GB Requirement
CC.6.1.2/CC.6.1.3

Grid Frequency Variations

CC.6.1.2 The **Frequency** of the **National Electricity Transmission System** shall be nominally 50Hz and shall be controlled within the limits of 49.5 - 50.5Hz unless exceptional circumstances prevail.

CC.6.1.3 The **System Frequency** could rise to 52Hz or fall to 47Hz in exceptional circumstances. Design of **User's Plant** and **Apparatus** and **OTSDUW Plant and Apparatus** must enable operation of that **Plant** and **Apparatus** within that range in accordance with the following:

Frequency Range	Requirement
51.5Hz - 52Hz	Operation for a period of at least 15 minutes is required each time the Frequency is above 51.5Hz.
51Hz - 51.5Hz	Operation for a period of at least 90 minutes is required each time the Frequency is above 51Hz.
49.0Hz - 51Hz	Continuous operation is required
47.5Hz - 49.0Hz	Operation for a period of at least 90 minutes is required each time the Frequency is below 49.0Hz.
47Hz - 47.5Hz	Operation for a period of at least 20 seconds is required each time the Frequency is below 47.5Hz.

For the avoidance of doubt, disconnection, by frequency or speed based relays is not permitted within the frequency range 47.5Hz to 51.5Hz, unless agreed with **NGET** in accordance with CC.6.3.12.

ENTSO-E Requirement
Article 8 (1)(a)(1)(Table 2)

Synchronous Area	Frequency Range	Time period for operation
Continental Europe	47.5 Hz – 48.5 Hz	To be defined by each TSO while respecting the provisions of Article 4(3), but not less than 30 minutes
	48.5 Hz – 49.0 Hz	To be defined by each TSO while respecting the provisions of Article 4(3), but not less than the period for 47.5 Hz – 48.5 Hz
	49.0 Hz – 51.0 Hz	Unlimited
	51.0 Hz – 51.5 Hz	30 minutes
Nordic	47.5 Hz – 48.5 Hz	30 minutes
	48.5 Hz – 49.0 Hz	To be defined by each TSO while respecting the provisions of Article 4(3), but not less than 30 minutes
	49.0 Hz – 51.0 Hz	Unlimited
	51.0 Hz – 51.5 Hz	30 minutes
Great Britain	47.0 Hz – 47.5 Hz	20 seconds
	47.5 Hz – 48.5 Hz	90 minutes
	48.5 Hz – 49.0 Hz	To be defined by each TSO while respecting the provisions of Article 4(3), but not less than 90 minutes
	49.0 Hz – 51.0 Hz	Unlimited
	51.0 Hz – 51.5 Hz	90 minutes
	51.5 Hz – 52.0 Hz	15 minutes
Ireland	47.5 Hz – 48.5 Hz	90 minutes
	48.5 Hz –	To be defined by each

	49.0 Hz	TSO while respecting the provisions of Article 4(3), but not less than 90 minutes
	49.0 Hz – 51.0 Hz	Unlimited
	51.0 Hz – 51.5 Hz	90 minutes
Baltic	47.5 Hz – 48.5 Hz	To be defined by each TSO while respecting the provisions of Article 4(3), but not less than 30 minutes
	48.5 Hz – 49.0 Hz	To be defined by each TSO while respecting the provisions of Article 4(3), but not less than the period for 47.5 Hz – 48.5 Hz
	49.0 Hz – 51.0 Hz	Unlimited
	51.0 Hz – 51.5 Hz	To be defined by each TSO while respecting the provisions of Article 4(3), but not less than 30 minutes

Table 2: Minimum time periods for which a Power Generating Module shall be capable of operating for different frequencies deviating from a nominal value without disconnecting from the Network.

In this example we could leave the GB Grid Code more or less as it is as it is fully consistent with the requirements of the ENTSO-E RfG although it is acknowledged that some of the definitions relating explicitly to Generators needs to be considered. It is also expected that the RfG will require the same frequency ranges as the DCC and HVDC Network Code so there is some scope here for a common set of requirements. An example of the combined text is illustrated below.

Grid Frequency Variations

CC.6.1.2 The **Frequency** of the **National Electricity Transmission System** shall be nominally 50Hz and shall be controlled within the limits of 49.5 - 50.5Hz unless exceptional circumstances prevail.

CC.6.1.3 The **System Frequency** could rise to 52Hz or fall to 47Hz in exceptional circumstances. Design of **Type A, B, C** and **D Power Generating Modules** must enable operation of that **Power Generating Module** within that range in accordance with the following:

Frequency Range	Requirement
51.5Hz - 52Hz	Operation for a period of at least 15 minutes is required each time the Frequency is above 51.5Hz.
51Hz - 51.5Hz	Operation for a period of at least 90 minutes is required each time the Frequency is above 51Hz.
49.0Hz - 51Hz	Continuous operation is required
47.5Hz - 49.0Hz	Operation for a period of at least 90 minutes is required each time the Frequency is below 49.0Hz.
47Hz - 47.5Hz	Operation for a period of at least 20 seconds is required each time the Frequency is below 47.5Hz.

For the avoidance of doubt, disconnection, by frequency or speed based relays is not permitted within the frequency range 47.5Hz to 51.5Hz, unless agreed with **NGET** in accordance with CC.6.3.12.

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Example 2 - Voltage Range CC.6.1.4

<table>
<tr><th>GB Requirement
CC.6.1.4</th><th>ENTSO-E Requirement
Article 11 (2)(a) Tables 6.1 and 6.2</th></tr>
<tr><td>
<u>Grid Voltage Variations</u>

CC.6.1.4 Subject as provided below, the voltage on the 400kV part of the National Electricity Transmission System at each Connection Site with a User (and in the case of OTSDUW Plant and Apparatus, a Transmission Interface Point) will normally remain within ±5% of the nominal value unless abnormal conditions prevail. The minimum voltage is -10% and the maximum voltage is +10% unless abnormal conditions prevail, but voltages between +5% and +10% will not last longer than 15 minutes unless abnormal conditions prevail. Voltages on the 275kV and 132kV parts of the National Electricity Transmission System at each Connection Site with a User (and in the case of OTSDUW Plant and Apparatus, a Transmission Interface Point) will normally remain within the limits ±10% of the nominal value unless abnormal conditions prevail. At nominal System voltages below 132kV the voltage of the National Electricity
</td><td>
<u>Voltage Range</u>

Type D Power Generating Modules shall fulfil the following requirements referring to Voltage stability:

a) With regard to Voltage ranges:

While still respecting the provisions according to Articles 9(3) (a) and 11(3) (a), a Power Generating Module shall be capable of staying connected to the Network and operating within the ranges of the Network Voltage at the Connection Point, expressed by the Voltage at the Connection Point related to nominal Voltage (per unit), and the time periods specified by tables 6.1 and 6.2.

<table>
<tr><th>Synchronous Area</th><th>Voltage Range</th><th>Time period for operation</th></tr>
<tr><td rowspan="3">Continental Europe</td><td>0.85 pu – 0.90 pu</td><td>60 minutes</td></tr>
<tr><td>0.90 pu – 1.118 pu</td><td>Unlimited</td></tr>
<tr><td>1.118 pu – 1.15 pu</td><td>To be decided by each TSO while respecting the provisions of Article 4(3), but not less than 20 minutes</td></tr>
<tr><td rowspan="2">Nordic</td><td>0.90 pu – 1.05 pu</td><td>Unlimited</td></tr>
<tr><td>1.05 pu – 1.10 pu</td><td>60 minutes</td></tr>
<tr><td>Great Britain</td><td>0.90 pu–1.10 pu</td><td>Unlimited</td></tr>
<tr><td>Ireland</td><td>0.90 pu – 1.118 pu</td><td>Unlimited</td></tr>
<tr><td rowspan="2">Baltic</td><td>0.85 pu – 0.90 pu</td><td>30 minutes</td></tr>
<tr><td>0.90 pu – 1.12 pu</td><td>Unlimited</td></tr>
</table>
</td></tr>
</table>

Transmission System at each **Connection Site** with a **User** (and in the case of **OTSDUW Plant and Apparatus**, a **Transmission Interface Point**) will normally remain within the limits ±6% of the nominal value unless abnormal conditions prevail. Under fault conditions, voltage may collapse transiently to zero at the point of fault until the fault is cleared. The normal operating ranges of the **National Electricity Transmission System** are summarised below: <u>National Electricity Transmission System Nominal Voltage</u> — <u>Normal Operating Range</u> 400kV — 400kV ±5% 275kV — 275kV ±10% 132kV — 132kV ±10% **NGET** and a **User** may agree greater or lesser variations in voltage to those set out above in relation to a particular **Connection Site**, and insofar as a greater or lesser variation is agreed, the relevant figure set out above shall, in relation to that	Table 6.1: This table shows the minimum time periods a Power Generating Module shall be capable of operating for Voltages deviating from the nominal value at the Connection Point without disconnecting from the Network. (The Voltage base for pu values is from 110 kV to 300 kV (excluding).) (table below) Table 6.2: This table shows the minimum time periods a Power Generating Module shall be capable of operating for Voltages deviating from the nominal value at the Connection

Synchronous Area	**Voltage Range**	**Time period for operation**
Continental Europe	0.85 pu – 0.90 pu	60 minutes
	0.90 pu – 1.05 pu	Unlimited
	1.05 pu – 1.0875 pu	To be decided by each TSO while respecting the provisions of Article 4(3), but not less than 60 minutes
	1.0875 pu – 1.10 pu	60 minutes
Nordic	0.90 pu – 1.05 pu	Unlimited
	1.05 pu – 1.10 pu	60 minutes
Great Britain	0.90 pu – 1.05 pu	Unlimited
	1.05 pu – 1.10 pu	15 minutes
Ireland	0.90 pu – 1.05 pu	Unlimited
Baltic	0.88 pu – 0.90 pu	20 minutes
	0.90 pu – 1.10 pu	Unlimited
	1.10 pu – 1.15 pu	20 minutes

User at the particular **Connection Site**, be replaced by the figure agreed.	Point without disconnecting from the Network. (The Voltage base for pu values is from 300 kV to 400 kV.) 1) While respecting the provisions of Article 4(3), wider Voltage ranges or longer minimum times for operation can be agreed between the Relevant Network Operator in coordination with the Relevant TSO and the Power Generating Facility Owner to ensure the best use of the technical capabilities of a Power Generating Module if needed to preserve or to restore system security. If wider Voltage ranges or longer minimum times for operation are economically and technically feasible, the consent of the Power Generating Facility Owner shall not be unreasonably withheld.

Notes

1) The GB requirements can be left more or less unchanged as they stand since (acknowledging that there may be a requirement for some amendments of the definitions) they are fully consistent with the ENTSO-E Code. However there are a couple of subtle differences between the two requirements. Under ENTSO-E RfG, voltages between 300kV and 110kV must be between ±10%. In GB at 275kV and 132kV the voltage range must be between ±10%. However in GB below 132kV the voltage range must be between ±6%. Clause 1) in the above Table states that wider voltage ranges or longer minimum times for operation can be agreed but it makes no mention of narrower ranges. It is unclear if there is some flexibility here or whether we will have to adopt the wider range which could undermine NGET's current security standards.

2) The voltage range requirements apply only to Type D Generating Units. Type D Power Generating Modules are either connected at 110kV or above or with a threshold of 30MW or more. The current GB Code applies only to direct connections (ie each connection site) but I suspect these ranges equally apply to the DCC and HVDC Code. In pre-empting the outcome of these codes there may be a need to hold fire or place a marker in the sand so the provisions between different classes of User are not duplicated.

Grid Voltage Variations

CC.6.1.4 Subject as provided below, the voltage on the 400kV part of the **National Electricity Transmission System** at each **Connection Site** with a **Type D Power Generating Module** will normally remain within ±5% of the nominal value unless abnormal conditions prevail. The minimum voltage is -10% and the maximum voltage is +10% unless abnormal conditions prevail, but voltages between +5% and +10% will not last longer than 15 minutes unless abnormal conditions prevail. Voltages on the 275kV and 132kV parts of the **National Electricity Transmission System** at each **Connection Site** with a **Type D Power Generating Module** will normally remain within the limits ±10% of the nominal value unless abnormal conditions prevail. At nominal **System** voltages below 132kV the voltage of the **National Electricity Transmission System** at each **Connection Site** with a **Type D Power Generating Module** will normally remain within the limits ±6% of the nominal value unless abnormal conditions prevail. Under fault conditions, voltage may collapse transiently to zero at the point of fault until the fault is cleared. The normal operating ranges of the **National Electricity Transmission System** are summarised below:

National Electricity Transmission System Nominal Voltage	Normal Operating Range
400kV	400kV ±5%
275kV	275kV ±10%
132kV	132kV ±10%

NGET and a **Type D Power Generating Facility Owner** may agree greater or lesser variations in voltage to those set out above in relation to a particular **Power Generating Module** at a **Connection Site**, and insofar as a greater or lesser variation is agreed, the relevant figure set out above shall, in relation to that **Type D Power Generating Facility Owner** at the particular **Connection Site**, be replaced by the figure agreed.

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Example 3 – Quality of Supply

GB Requirement CC.6.1.5	ENTSO-E Requirement Not specified
Voltage Waveform Quality CC.6.1.5 All **Plant** and **Apparatus** connected to the **National Electricity Transmission System**, and that part of the **National Electricity Transmission System** at each **Connection Site** or, in the case of **OTSDUW Plant and Apparatus**, at each **Interface Point**, should be capable of withstanding the following distortions of the voltage waveform in respect of harmonic content and phase unbalance: (a) Harmonic Content The **Electromagnetic Compatibility Levels** for harmonic distortion on the **Onshore Transmission System** from all sources under both **Planned Outage** and fault outage conditions, (unless abnormal conditions prevail) shall comply with the levels shown in the tables of Appendix A of **Engineering Recommendation** G5/4. The **Electromagnetic Compatibility Levels** for harmonic distortion on an **Offshore Transmission System** will be defined in relevant **Bilateral Agreements**. **Engineering Recommendation** G5/4 contains planning criteria which **NGET** will apply to the connection of non-linear **Load** to the **National Electricity Transmission System**, which may result in harmonic emission limits being specified for these **Loads** in the relevant **Bilateral Agreement**. The application of the planning criteria will take into account the position of existing and	ENTSO-E RfG does not specify Quality of Supply requirements other than in respect of Quality of Supply Monitoring Requirements as covered under Article 10 (6) (1) and Article 10 (6) (4).

prospective **Users' Plant** and **Apparatus** (and **OTSDUW Plant and Apparatus**) in relation to harmonic emissions. **Users** must ensure that connection of distorting loads to their **User Systems** do not cause any harmonic emission limits specified in the **Bilateral Agreement**, or where no such limits are specified, the relevant planning levels specified in **Engineering Recommendation** G5/4 to be exceeded. (b) <u>Phase Unbalance</u> Under **Planned Outage** conditions, the maximum **Phase (Voltage) Unbalance** on the **National Electricity Transmission System** should remain, in England and Wales, below 1%, and in Scotland, below 2%, unless abnormal conditions prevail and **Offshore** (or in the case of **OTSDUW**, **OTSDUW Plant and Apparatus**) will be defined in relevant **Bilateral Agreements**.	

Notes

Since Quality of Supply is not considered as a cross border issue it is not included in the ENTSO-E RfG other than in respect of Power Quality Monitoring. In GB the requirements for Power Quality Monitoring are generally captured under the Bilateral Agreement which would be considered to be consistent the ENTSO-E RfG. On this basis allowing for variations in the Glossary and Definitions and there being no requirements in the other Network Codes, such as the Demand Connection Code the best approach considered is to leave the text as is.

Example 4 – Output Power with Falling Frequency

GB Requirement	ENTSO-E Requirement

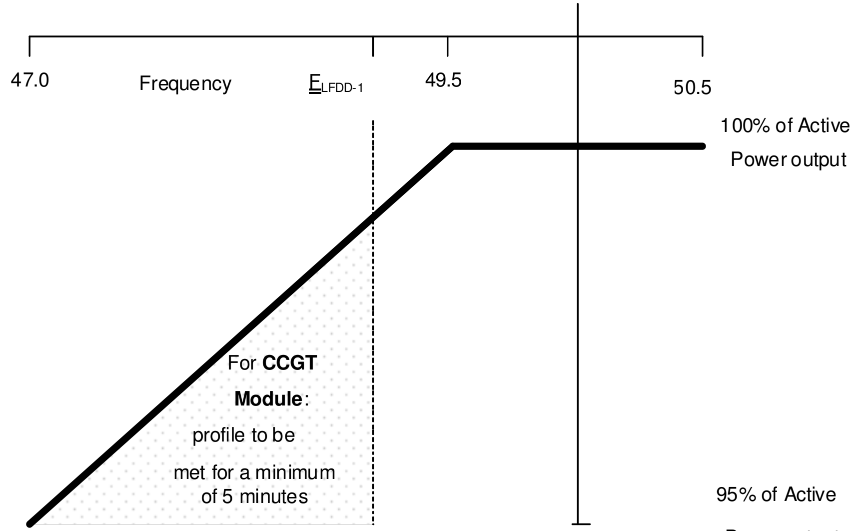
GB Requirement

Power Output with Falling Frequency

CC.6.3.3 Each **Generating Unit**, **DC Converter** (including an **OTSDUW DC Converter**), **Power Park Module** and/or **CCGT Module** must be capable of:

(a) continuously maintaining constant **Active Power** output for **System Frequency** changes within the range 50.5 to 49.5 Hz; and

(b) (subject to the provisions of CC.6.1.3) maintaining its **Active Power** output at a level not lower than the figure determined by the linear relationship shown in Figure 2 for **System Frequency** changes within the range 49.5 to 47 Hz, such that if the **System Frequency** drops to 47 Hz the **Active Power** output does not decrease by more than 5%. In the case of a **CCGT Module**, the above requirement shall be retained down to the **Low Frequency Relay** trip setting of 48.8 Hz, which reflects the first stage of the Automatic Low **Frequency**



Note: **Frequency** F_{LFDD-1} is the relay trip setting of the first stage of the Automatic Low **Frequency Demand Disconnection** Scheme

ENTSO-E Requirement

Power Output with Falling Frequency

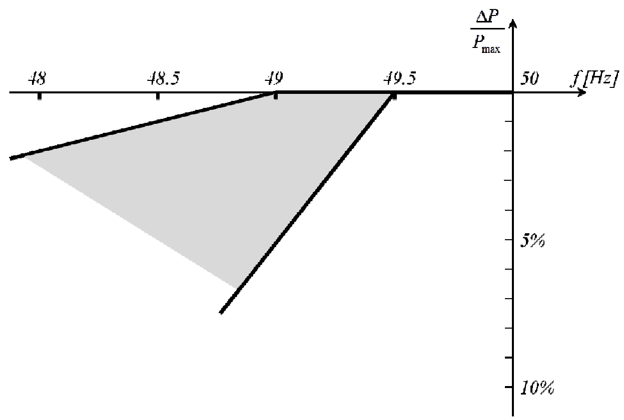
Article 8 (1) (d)(e) – Applicable to Type A Power Generating Units (which also includes the requirements for Types B, C and D Power Generating Modules

a) The Power Generating Module shall be capable of maintaining constant output at its target Active Power value regardless of changes in Frequency, unless output shall follow the defined changes in output in the context of Article 8(1) (c), (e) or Article 10(2) (b), and Article 10(2) (c) where applicable.

b) The Relevant TSO shall define admissible Active Power reduction from maximum output with falling Frequency within the boundaries, given by the full lines in Figure 2:

- Below 49 Hz falling by a reduction rate of 2 % of the Maximum Capacity at 50 Hz per 1 Hz Frequency drop;
- Below 49.5 Hzby a reduction rate of 10 % of the Maximum Capacity at 50 Hz per 1 Hz Frequency drop.

Applicability of this reduction is limited to a selection of affected generation technologies and may be subject to further conditions defined by the Relevant TSO while respecting the provisions of Article 4(3).



Demand Disconnection scheme notified to **Network Operators** under OC6.6.2. For **System Frequency** below that setting, the existing requirement shall be retained for a minimum period of 5 minutes while **System Frequency** remains below that setting, and special measure(s) that may be required to meet this requirement shall be kept in service during this period. After that 5 minutes period, if **System Frequency** remains below that setting, the special measure(s) must be discontinued if there is a materially increased risk of the **Gas Turbine** tripping. The need for special measure(s) is linked to the inherent **Gas Turbine Active Power** output reduction caused by reduced shaft speed due to falling **System Frequency**. Figure 2 (c) For the avoidance of doubt in the case of a **Generating Unit** or **Power Park Module** (or **OTSDUW DC Converters** at the **Interface Point**) using an **Intermittent Power Source** where the mechanical power input will not be constant over time, the requirement is that the **Active Power** output shall be independent of **System Frequency** under (a) above and should not drop with **System Frequency** by greater than the amount specified in (b) above. (d) A **DC Converter Station** must be capable of maintaining its **Active Power** input (i.e. when operating in a mode analogous to **Demand**) from the **National Electricity Transmission System** (or **User System** in the case of an **Embedded DC Converter Station**) at a level not greater than the figure determined by the linear relationship shown in Figure 3 for **System Frequency** changes within the range 49.5 to 47 Hz, such that if the **System Frequency** drops to 47.8 Hz the **Active Power** input decreases by more than 60%.	Figure 2 – Maximum power capability reduction with falling Frequency. The diagram represents the boundaries defined by the Relevant TSO while respecting the provisions of Article 4(3).

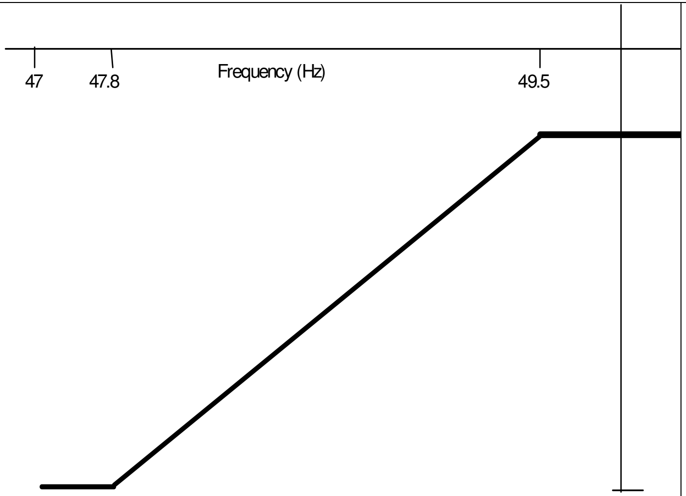


Figure 3

(e) At a **Large Power Station**, in the case of an **Offshore Generating Unit**, **Offshore Power Park Module**, **Offshore DC Converter** and **OTSDUW DC Converter**, the **Generator** shall comply with the requirements of CC.6.3.3. **Generators** should be aware that Section K of the **STC** places requirements on **Offshore Transmission Licensees** which utilise a **Transmission DC Converter** as part of their **Offshore Transmission System** to make appropriate provisions to enable **Generators** to fulfil their obligations.

(f) In the case of an **OTSDUW DC Converter** the **OTSDUW Plant and Apparatus** shall provide a continuous signal indicating the real time frequency measured at the **Interface Point** to the **Offshore Grid Entry Point**.

Notes – In this case the ENTSO-E requirements are fully consistent with the GB Grid Code and in theory could be largely left as is, though would need to state that it applies to all Type A, B, C and D Type Generating Modules. On the other hand the GB Code applies to DC Converters and Offshore Generator Build connections so there may need to be additional amendments when the HVDC Code is released.

On this basis, the following generic wording (in respect of Generating Units and Power Park Modules only) could be used. The track change marks in the text below utilises the existing GB Grid Code text and then applies the ENTSO-E RfG elements to it. As RfG only covers onshore and offshore Power Generating Modules the elements relating to HVDC and OTSDUW requirements have been omitted. In addition it is assumed that a number of definitions in the current GB Grid Code will remain unchanged but this will require further investigation.

Power Output with Falling Frequency

CC.6.3.3 Each Type A, B , C and D **Power Generating Module**, must be capable of:

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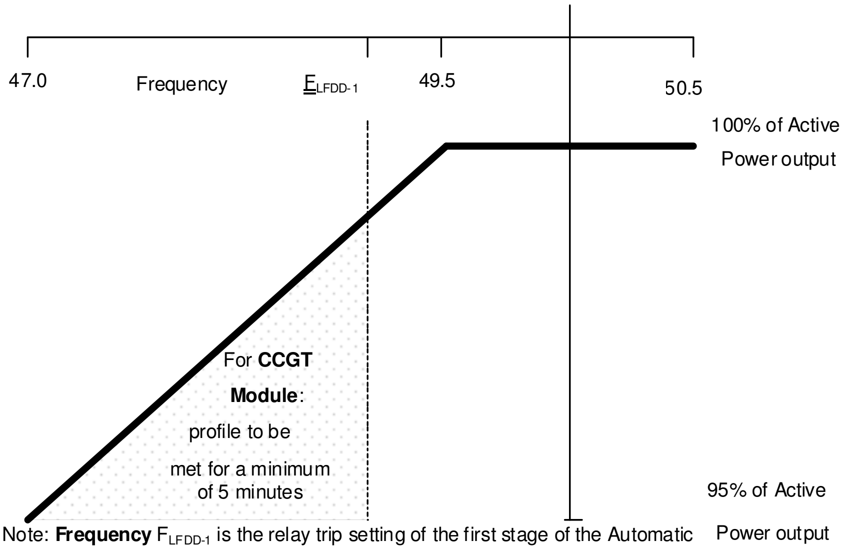
(a) continuously maintaining constant **Active Power** output for **System Frequency** changes within the range 50.5 to 49.5 Hz; and

(b) (subject to the provisions of CC.6.1.3) maintaining its **Active Power** output at a level not lower than the figure determined by the linear relationship shown in Figure 2 for **System Frequency** changes within the range 49.5 to 47 Hz, such that if the **System Frequency** drops to 47 Hz the **Active Power** output does not decrease by more than 5%. In the case of a **CCGT Module**, the above requirement shall be retained down to the **Low Frequency Relay** trip setting of 48.8 Hz, which reflects the first stage of the Automatic Low **Frequency Demand Disconnection** scheme notified to **Network Operators** under OC6.6.2. For **System Frequency** below that setting, the existing requirement shall be retained for a minimum period of 5 minutes while **System Frequency** remains below that setting, and special measure(s) that may be required to meet this requirement shall be kept in service during this period. After that 5 minutes period, if **System Frequency** remains below that setting, the special measure(s) must be discontinued if there is a materially increased risk of the **Gas Turbine** tripping. The need for special measure(s) is linked to the inherent **Gas Turbine Active Power** output reduction caused by reduced shaft speed due to falling **System Frequency**.

Figure 2



Note: **Frequency** F_{LFDD-1} is the relay trip setting of the first stage of the Automatic Low **Frequency Demand Disconnection** Scheme

(c) For the avoidance of doubt, in the case of any **Synchronous Power Generating Module** or **Power Park Module** using an **Intermittent Power Source** where the mechanical power input will not be constant over time, the requirement is that the **Active Power** output shall be independent of **System Frequency** under (a) above and should not drop with **System Frequency** by greater than the amount specified in (b) above.

Figure 3

(e) Type A, B, C and D **Power Generating Modules** shall comply with the requirements of CC.6.3.3. **Generators** should be aware that Section K of the **STC** places requirements on **Offshore Transmission Licensees** which utilise a **Transmission DC Converter** as part of their **Offshore Transmission System** to make appropriate provisions to enable **Generators** to fulfil their obligations.

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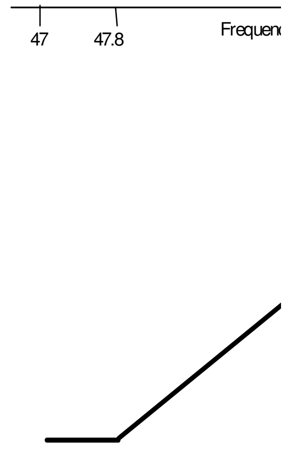
Deleted: (or **OTSDUW DC Converters** at the **Interface Point**)

Deleted: (d) . A **DC Converter Station** must be capable of maintaining its **Active Power** input (i.e. when operating in a mode analogous to **Demand**) from the **National Electricity Transmission System** (or **User System** in the case of an **Embedded DC Converter Station**) at a level not greater than the figure determined by the linear relationship shown in Figure 3 for **System Frequency** changes within the range 49.5 to 47 Hz, such that if the **System Frequency** drops to 47.8 Hz the **Active Power** input decreases by more than 60%.¶



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Deleted: At a **Large Power Station**, in the case of an **Offshore Generating Unit**, **Offshore Power Park Module**, **Offshore DC Converter** and **OTSDUW DC Converter**, the **Generator**

Deleted: (f) . In the case of an **OTSDUW DC Converter** the **OTSDUW Plant and Apparatus** shall provide a continuous signal indicating the real time frequency measured at the **Interface Point** to the **Offshore Grid Entry Point**.¶

Example 5 – Black Start

GB Requirement CC.6.3.5	ENTSO-E Requirement Article 10(5)(a)
CC.6.3.5 – Black Start CC.6.3.5 It is an essential requirement that the **National Electricity Transmission System** must incorporate a **Black Start Capability**. This will be achieved by agreeing a **Black Start Capability** at a number of strategically located **Power Stations**. For each **Power Station NGET** will state in the **Bilateral Agreement** whether or not a **Black Start Capability** is required.	Article 10 (5)(a) 5. Type C Power Generating Modules shall fulfil the follo requirements referring to system restoration: a) With regard to Black Start Capability: 1) Black Start Capability is not mandatory. If Relevant TSO deems system security to be at risk to a lack of Black Start Capability in a Control the Relevant TSO shall have the right to obta quote for Black Start Capability from P Generating Facility Owners. 2) A Power Generating Module with a Black Capability shall be able to start from shut down w a timeframe decidedby the Relevant Net Operator in coordination with the Relevant TSO respecting the provisions ofArticle 4(3),without external energy supply. The Power Gener Module shall be able to synchronise within Frequency limits defined in Article 8(1) and Vo limits defined by the Relevant Network Operat defined by Article 11(2) where applicable. 3) The Power Generating Module Voltage regulation shall be capable of regulating load connections causing dips of Voltage automatically. The Power Generating Module shall:

	- be capable of regulating load connections in block load; - control Frequency in case of overfrequency and underfrequency within the whole Active Power output range between Minimum Regulating Level and Maximum Capacity as well as at houseload level; - be capable of parallel operation of a few Power Generating Modules within one island; and - controlVoltage automatically during the system restoration phase.

In this case there will be a need to re-write section CC.6.3.5 of the Grid Code. A possible example of how this could be achieved is as follows. The original text is based on the current wording of the GB Grid Code and the text in track change marked format is the new text.

CC.6.3.5 It is an essential requirement that the **National Electricity Transmission System** must incorporate a **Black Start Capability**. This will be achieved by agreeing a **Black Start Capability** (through a negotiated contract) at a number of strategically located **Type C** and **Type D** **Power** **Generating Modules**. Each **Type C** and **Type D** **Power** **Generating Module** will be required to provide, upon notification from **NGET**, the cost of providing a **Black Start Capability**. **NGET** will state in the **Bilateral Agreement** whether or not a **Black Start Capability** is required. For the avoidance of doubt **Black Start Stations** will be required to comply with the requirements of OC5.7 and OC9.

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Notes

i) *The current GB Grid simply states that a Black Start Capability may be required, the requirements for a Black Start Capability would be specified in the Bilateral Agreement with the full details and specifications being detailed in the Black Start Contract. The Black Start Contract will specify all of the technical requirements over and above those specified in the ENTSO-E RfG.*

ii) *The Black Start arrangements in GB only apply to Medium and Large Power Stations.*

APPENDIX B

Draft Fault Ride Through Text with GB Terms and RfG Requirements

Based on Issue 5, Revision 0 of the GB Grid Code and

ENTSO-E Requirements for Generators dated 26 June 2012

Including requirements for all Type A – D Power Generating Modules

Index

CC.6.3.15.8	Other **Power Park Module** Fault Ride Through requirements applicable to **Type B**, **Type C** and **Type D Power Park Modules**	CC.6.3.15.3	Not specified – taken from GB Grid Code	12
CC.A.4A.1	Fault Ride Through requirements for **Type B** and **Type C Synchronous Power Generating Modules** - Examples	Connection Conditions – Appendix 4	Not specified – example taken from GB Grid Code	14
CC.A.4A.2.	Fault Ride Through requirements for **Type D Synchronous Power Generating Modules** - Examples	Connection Conditions – Appendix 4	Not specified – example taken from GB Grid Code	17
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Draft Fault Ride Through Text with GB Terms and RfG Requirements

Based on Issue 5, Revision 0 of the GB Grid Code and

ENTSO-E Requirements for Generators dated 26 June 2012

CC.6.3.15 Fault Ride Through

This section sets out the general fault ride through requirements applicable to all **Power Generating Modules**. For the avoidance of doubt, there is no requirement for **Type A Power Generating Modules**, **Type A Synchronous Power Generating Modules** or **Type A Power Park Modules** to meet any fault ride through requirements.

CC.6.3.15.1 Fault Ride Through requirements applicable to **Type B** and **Type C Synchronous Power Generating Modules**

(a) Each **Type B** and **Type C Synchronous Power Generating Module** is required to:-

(i) remain transiently stable and connected to the **System** without tripping of any **Type B** or **Type C Synchronous Power Generating Module** for any balanced or unbalanced fault on the **System** where the voltage at the **Connection Point** remains anywhere on or above the heavy black line shown in Figure 5.1.The corresponding parameters are defined in Table 5.1. and Appendix 4 Figures CC.A.4A.2 (a), (b) and (c) provide an explanation and illustrations of Figure 5.1, and;

(ii) provide **Active Power** output at the **Connection Point** as described in Figure 5.1, atleast in proportion to the retained voltage of the lowest phase, and;.)

(iii) restore **Active Power** output following **Voltage** dips at the **Connection Point**as described in Figure 5.1, within 0.5 seconds of restoration of the voltage at the **Connection Point** to the minimum levels specified in CC.6.1.4 to at least 90% of the level available immediately before the occurrence of the fault.

Comment [A1]: Under the Current GB Grid Code, Active Power Recovery is required within 0.5 seconds for faults upto 140ms and 1 second for faults in excess of 140ms. This will cause a slight issue for the RfG implementation. We can have a dual requirement which states for faults upto 140ms a 0.5 second recovery is required and for faults in excess of 140ms a 1 second recovery is required.

(b)(i) In addition, once the **Active Power** output has been restored to the required level before the fault, **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.

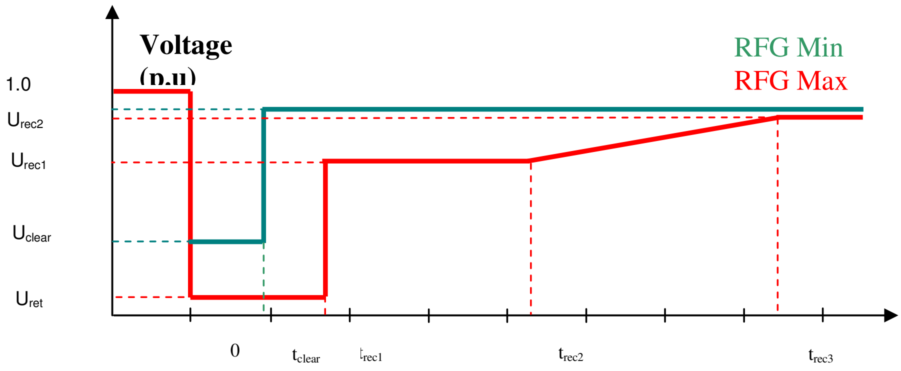

Figure 5.1 Fault Ride Through profile required for **Type B** and **Type C Power Generating Modules**. The diagram represents the lower limit of a voltage against time profile by the voltage at the **Connection Point**, expressed by the ratio of its actual value and its nominal value in per unit before, during and after a fault. Uret is the retained voltage at the **Connection Point**. During a fault, tclear is the instant when the fault has been cleared. Urec1, Urec2, trec1, trec2 and trec3 specify certain points of lower limits of Voltage recovery after fault clearance.

(Note:- NGET will need to define the voltage against time profile which will be somewhere between the Green and Red Curves)

Voltage parameters (p.u)		Time parameters (seconds)	
U_{ret}:	0.05 – 0.3	t_{clear}	0.14 – 0.25
U_{clear}:	0.7 – 0.9	t_{rec1}	t_{clear}
U_{rec1}:	U_{clear}	t_{rec2}	T_{rec1} – *0.7*
$U_{rec\ 2}$:	0.85 – 0.9 and U_{clear}	t_{rec3}	T_{rec2} - 1.5

Table 5.1 Parameters for Figure 5.1 for fault ride through capability of **Type B** and **Type C Synchronous Power Generating Modules**

(ii) During the period of the fault as detailed in CC.6.3.15.1(a)(i) for which the voltage at the **Connection Point** is outside the limits specified in CC.6.1.4, each **Type B** and **Type C Synchronous Power Generating Module** shall generate maximum reactive current without exceeding the transient rating limit of the **Type B** or **Type C Synchronous Power Generating Module**.

(iii) **NGET** shall define the fault ride through pre-fault and post fault conditions at the **Connection Point** in the **Bilateral Agreement**. This will include details of:-

- conditions for the calculation of the pre-fault minimum short circuit capacity at the **Connection Point**
- conditions for the pre-fault active and **Reactive Power** operating point of the **Power Generating Module** at the **Connection Point** and voltage at the **Connection Point** and
- conditions for the calculation of the post – fault minimum short circuit capacity at the **Connection Point**.

_(iv) **NGET** shall provide upon request to the **Generator**, the pre-fault and post fault conditions to be considered for fault ride through as an outcome of the calculations at the **Connection Point**. This shall include:-

Comment [A2]: In RfG Terms this would be the Power Generating Facility Owner

- pre-fault minimum short circuit capacity at each **Connection Point** expressed in MVA.

- pre-fault operating point of the **Power Generating Module** expressed in **Active Power** output and **Reactive Power** output at the **Connection Point** and voltage at the **Connection Point**; and

- post fault minimum short circuit capacity at each **Connection Point** expressed in MVA

- alternatively generic values for the above conditions derived from typical cases may be provided by **NGET** or **Network Operator**.

Comment [A3]: Do we need to make reference to the Relevant Transmission Licensee here.

(v) The **Generator** shall ensure that the under voltage protection at the **Connection Point** shall be set by the **Generator** to the widest possible range so that it does not impinge on the ability of the **Type B** or **Type C Synchronous Power Generating Module** to satisfy the fault ride through requirements defined in CC.6.3.15.1 of the Grid Code unless **NGET** has agreed to any relays which will trip the **Synchronous Power Generating Module**. **Generators** shall ensure the protection schemes and settings for internal electrical faults shall be designed not to jeopardise fault ride through performance.

CC.6.3.15.2 Fault Ride Through requirements applicable to **Type D Synchronous Power Generating Modules**

(a) Each **Type D Synchronous Power Generating Module** is required to:-

(i) remain transiently stable and connected to the **System** without tripping of any **Type D Synchronous Power Generating Module** for any balanced or unbalanced fault on the **System** where the voltage at the **Connection Point** remains anywhere on or above the heavy black line shown in Figure 5.2. The corresponding parameters are defined in Table 5.2 and Appendix 4 Figures CC.A.4B.2 provide an explanation and illustrations of Figure 5.2;

(ii) provide **Active Power** output at the **Connection Point** as described in Figure 5.2, atleast in proportion to the retained voltage of the lowest phase).

(iii) restore **Active Power** output following **Voltage** dips at the **Connection Point** asdescribed in Figure 5.2, within 0.5 seconds of restoration of the voltage at the **Connection Point** to the minimum levels specified in CC.6.1.4 to at least 90% of the level available immediately before the occurrence of the fault.

Comment [A4]: Under the Current GB Grid Code, Active Power Recovery is required within 0.5 seconds for faults upto 140ms and 1 second for faults in excess of 140ms. This will cause a slight issue for the RfG implementation. We can have a dual requirement which states for faults upto 140ms a 0.5 second recovery is required and for faults in excess of 140ms a 1 second recovery is required.

(b)(i) In addition once the **Active Power** output has been restored to the required level, before the fault, **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.

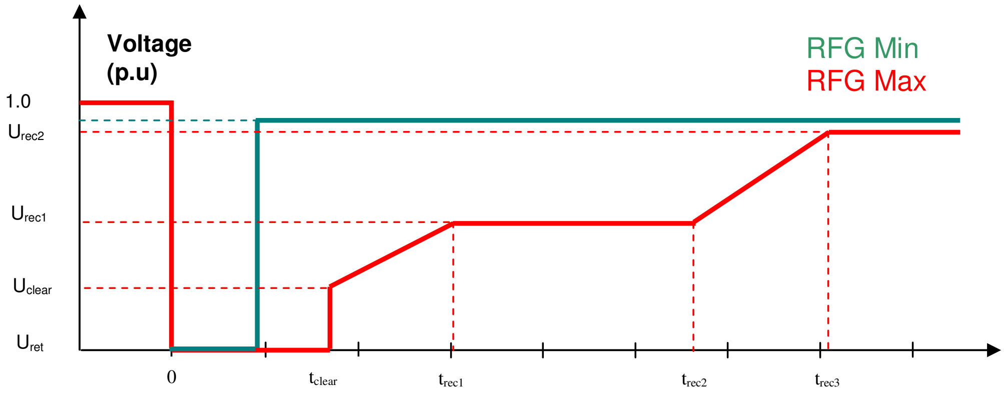

Figure 5.2 Fault Ride Through profile required for **Type D Power Generating Modules**. The diagram represents the lower limit of a voltage against time profile by the voltage at the **Connection Point**, expressed by the ratio of its actual value and its nominal value in per unit before, during and after a fault. Uret is the retained voltage at the **Connection Point**. During a fault, tclear is the instant when the fault has been cleared. Urec1, Urec2, trec1, trec2 and trec3 specify certain points of lower limits of Voltage recovery after fault clearance.

(Note:- NGET will need to define the voltage against time profile which will be somewhere between the Green and Red Curves)

Voltage parameters (p.u)		Time parameters (seconds)	
U_{ret}:	0	t_{clear}	0.14 – 0.25
U_{clear}:	0.25	t_{rec1}	t_{clear} – 0.45
U_{rec1}:	0.5 – 0.7	t_{rec2}	t_{rec1} – 0.7
$U_{rec\,2}$:	0.85 – 0.9	t_{rec3}	t_{rec2} - 1.5

Table 5.2 Parameters for Figure 5.2 for fault ride through capability of **Type D Synchronous Power Generating Modules**

(ii) During the period of the fault as detailed in CC.6.3.15.2(b)(i) for which the voltage at the **Connection Point** is outside the limits specified in CC.6.1.4, each **Type D Synchronous Power Generating Module** shall generate maximum reactive current without exceeding the transient rating limit of the **Type D Synchronous Power Generating Module**.

(v) **NGET** shall define the fault ride through pre-fault and post fault conditions at the **Connection Point** in the **Bilateral Agreement**. This will include details of:-

- conditions for the calculation of the pre-fault minimum short circuit capacity at the **Connection Point**

- conditions for the pre-fault active and **Reactive Power** operating point of the **Power Generating Module** at the **Connection Point** and voltage at the **Connection Point** and

- conditions for the calculation of the post – fault minimum short circuit capacity at the **Connection Point**.

(vi) **NGET** shall provide upon request to the **Generator**, the pre-fault and post fault conditions to be considered for fault ride through as an outcome of the calculations at the **Connection Point**. This shall include:-

- pre-fault minimum short circuit capacity at each **Connection Point** expressed in MVA.

- pre-fault operating point of the **Power Generating Module** expressed in **Active Power** output and **Reactive Power** output at the **Connection Point** and voltage at the **Connection Point**; and

- post fault minimum short circuit capacity at each **Connection Point** expressed in MVA

- alternatively generic values for the above conditions derived from typical cases may be provided by **NGET** or **Network Operator**.

Comment [A5]: In RfG Terms this would be the Power Generating Facility Owner

Comment [A6]: Do we need to make reference to the Relevant Transmission Licensee here.

(v) The **Generator** shall ensure that the under voltage protection at the **Connection Point** shall be set by the **Generator** to the widest possible range so that it does not impinge on the ability of the **Type D Synchronous Power Generating Module** to satisfy the fault ride through requirements defined in CC.6.3.15.2 of the Grid Code unless **NGET** has agreed to any relays which will trip the **Type D Synchronous Power Generating Module**. **Generators** shall ensure the protection schemes and settings for internal electrical faults shall be designed not to jeopardise fault ride through performance.

CC.6.3.15.3 Fault Ride Through requirements applicable to **Type B** and **Type C Power Park Modules**

(a) Each **Type B** and **Type C Power Park Module** is required to:-

(i) remain transiently stable and connected to the **System** without tripping of any **Type B** or **Type C Power Park Module** for any balanced or unbalanced fault on the **System** where the voltage at the **Connection Point** remains anywhere on or above the heavy black line shown in Figure 5.3.The corresponding parameters are defined in Table 5.3. and Appendix 4 Figures CC.A.4.C.2 (a), (b) and (c) provide an explanation and illustrations of Figure 5.3, and;

(ii) provide **Active Power** output at the **Connection Point** as described in Figure 5.3, at least in proportion to the retained voltage of the lowest phase, and;.

(iii) restore **Active Power** output following **Voltage** dips at the **Connection Point** as described in Figure 5.3, within 0.5 seconds of restoration of the voltage at the **Connection Point** to the minimum levels specified in CC.6.1.4 to at least 90% of the level available immediately before the occurrence of the fault.

Comment [A7]: Under the Current GB Grid Code, Active Power Recovery is required within 0.5 seconds for faults upto 140ms and 1 second for faults in excess of 140ms. This will cause a slight issue for the RfG implementation. We can have a dual requirement which states for faults upto 140ms a 0.5 second recovery is required and for faults in excess of 140ms a 1 second recovery is required.

(b)(i) In addition, once the **Active Power** output has been restored to the required level before the fault, **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.

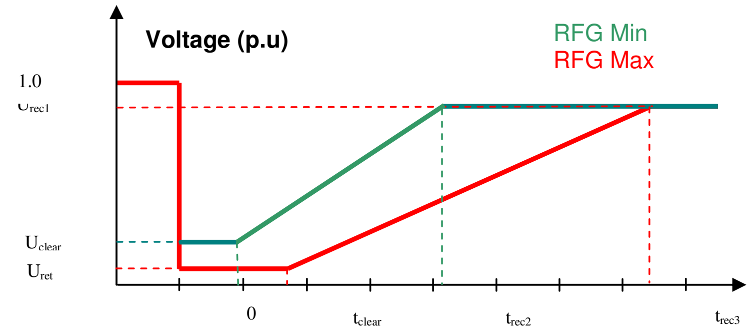

Figure 5.3 Fault Ride Through profile required for **Type B** and **Type C Power Park Modules**. The diagram represents the lower limit of a voltage against time profile by the voltage at the **Connection Point**, expressed by the ratio of its actual value and its nominal value in per unit before, during and after a fault. Uret is the retained voltage at the **Connection Point**. During a fault, tclear is the instant when the fault has been cleared. Urec1, Urec2, trec1, trec2 and trec3 specify certain points of lower limits of Voltage recovery after fault clearance.

(Note:- NGET will need to define the voltage against time profile which will be somewhere between the Green and Red Curves)

Voltage parameters (p.u)		Time parameters (seconds)	
U_{ret}:	0.05 – 0.15	t_{clear}	0.14 – 0.25
U_{clear}:	U_{ret} – 0.15	t_{rec1}	t_{clear}
U_{rec1}:	U_{clear}	t_{rec2}	trec1
$U_{rec\ 2}$:	0.85	t_{rec3}	1.5 – 3.0

Table 5.3 Parameters for Figure 5.3 for fault ride through capability of **Type B** and **Type C Power Park Modules**

(ii) During the period of the fault as detailed in CC.6.3.15.3(a)(i) for which the voltage at the **Connection Point** is outside the limits specified in CC.6.1.4, each **Type B** and **Type C Power Park Module** is required to satisfy the additional reactive current injection requirements defined in CC.6.3.15.4.

(iii) **NGET** shall define the fault ride through pre-fault and post fault conditions at the **Connection Point** in the **Bilateral Agreement**. This will include details of:-

- conditions for the calculation of the pre-fault minimum short circuit capacity at the **Connection Point**
- conditions for the pre-fault active and **Reactive Power** operating point of the **Power Generating Module** at the **Connection Point** and voltage at the **Connection Point** and
- conditions for the calculation of the post – fault minimum short circuit capacity at the **Connection Point**.

_(iv) **NGET** shall provide upon request to the **Generator**, the pre-fault and post fault conditions to be considered for fault ride through as an outcome of the calculations at the **Connection Point**. This shall include:-

- pre-fault minimum short circuit capacity at each **Connection Point** expressed in MVA.
- pre-fault operating point of the **Power Park Module** expressed in **Active Power** output and **Reactive Power** output at the **Connection Point** and voltage at the **Connection Point**; and
- post fault minimum short circuit capacity at each **Connection Point** expressed in MVA
- alternatively generic values for the above conditions derived from typical cases may be provided by **NGET** or **Network Operator**.

Comment [A8]: In RfG Terms this would be the Power Generating Facility Owner

Comment [A9]: Do we need to make reference to the Relevant Transmission Licensee here.

(v) The **Generator** shall ensure that the under voltage protection at the **Connection Point** shall be set by the **Generator** to the widest possible range so that it does not impinge on the ability of the **Type B** or **Type C Power Park Module** to satisfy the fault ride through requirements defined in CC.6.3.15.3.8 of the Grid Code unless **NGET** has agreed to any relays which will trip the **Power Park Module**. **Generators** shall ensure the protection schemes and settings for internal electrical faults shall be designed not to jeopardise fault ride through performance.

CC.6.3.15.4 Fast Acting additional reactive current requirements applicable to **Type B** and **Type C Power Park Modules**

(a) Each **Type B** and **Type C Power Park Module** is required to:-

(i) inject fast acting additional reactive current at the **Connection Point** during symmetrical (3 phase) faults and disturbances. Each **Type B** or **Type C Power Park Module** shall be capable of either:

(1) ensuring the supply of additional reactive current at the **Connection Point** according to further specifications by the **Relevant Transmission Licensee** and **Relevant Network Operator** in co-ordination with **NGET** of the magnitude of this current, depending on the deviation of the voltage at the **Connection Point** from its nominal value or:

(2) alternatively, measuring voltage deviations at the terminals of the

individual units of the **Power Park Module** and providing additional reactive current at the terminals of these units according to further specifications by the **Relevant Transmission Licensee** and/or **Network Operator** in coordination with **NGET** of the magnitude of this current, depending on the deviation of the voltage at unit's terminals from its nominal value.

(ii) In addition each **Type B** and **Type C Power Park Module** (CC.6.3.15.4(a)(i)(1)) or the individual units of the **Power Park Module** (CC.6.3.15.4(a)(ii)(2)) shall be capable of providing at least 2/3 of the additional reactive current within a time period specified by **NGET** which shall not be less than 10ms. The target value of this additional reactive current defined by CC.6.3.15.4(a)(i)(1) shall be reached with an accuracy of 10% within 60ms from the moment the voltage deviation has occurred as further specified according to CC.6.3.15.4(a)(1).

(iii) The total reactive current contribution shall be not more than 1p.u of the short term dynamic current rating (covering 0.4 seconds) of the **Power Park Module** (CC.6.3.15.4(a)(i)(1)) or the individual units of the **Power Park Module** (CC.6.3.15.4(a)(i)(2)) taking into account the pre-fault reactive current. If additional real current injection is given priority over additional reactive current injection, the total current contribution can be further limited by the real current based on limiting the apparent current (vector addition of real and reactive current) to 1p.u of the short term dynamic rating of the **Power Park Module** (CC.6.3.15.4(a)(i)(1)) or the individual units of the **Power Park Module** (CC.6.3.15.4(a)(i)(2)).

(iv) With regard to fast acting additional reactive current injection in the case of asymmetrical (1-phase or 2-phase) faults the **Network Operator** in coordination with **NGET** shall define the requirements for asymmetrical current injection.

Comment [A10]: All of this text is new to the GB Grid Code. There are a number of sections which are both unclear and also require some internal modelling work to determine the GB Requirements. In view of this, signinificant re-vision to this section of the wording + modelling work will be required to define the requirements. There is however no problem in implenting these types of requirements into the GB Grid Code.

CC.6.3.15.5 Additional Fault Ride Through requirements applicable to **Type C Power Park Modules**

NGET in coordination with **Relevant Transmission Licensees** and **Network Operators** shall define whether **Active Power** contribution or **Reactive Power** contribution has priority during faults for which fault ride through capability is required. If priority is given to **Active Power** contribution, its provision shall be established no later than 150ms from fault inception.

CC.6.3.15.6 Fault Ride Through requirements applicable to **Type D Power Park Modules**

(a) Each **Type D Power Park Module** is required to:-

(ii) remain transiently stable and connected to the **System** without tripping of any **Type D Power Park Module** for any balanced or unbalanced fault on the **System** where the voltage at the **Connection Point** remains anywhere on or above the heavy black line shown in Figure 5.4. The corresponding parameters are defined in Table 5.4. and Appendix 4 Figures CC.A.4.D.2 (a) (b) and (c) provide an explanation and illustrations of Figure 5.4, and;

(ii) provide **Active Power** output at the **Connection Point** as described in Figure 5.4, at least in proportion to the retained voltage of the lowest phase, and;.

(iii) restore **Active Power** output following **Voltage** dips at the **Connection Point** as described in Figure 5.4, within 0.5 seconds of restoration of the voltage at the **Connection Point** to the minimum levels specified in CC.6.1.4 to at least 90% of the level available immediately before the occurrence of the fault.

(b)(i) In addition, once the **Active Power** output has been restored to the required level before the fault, **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.

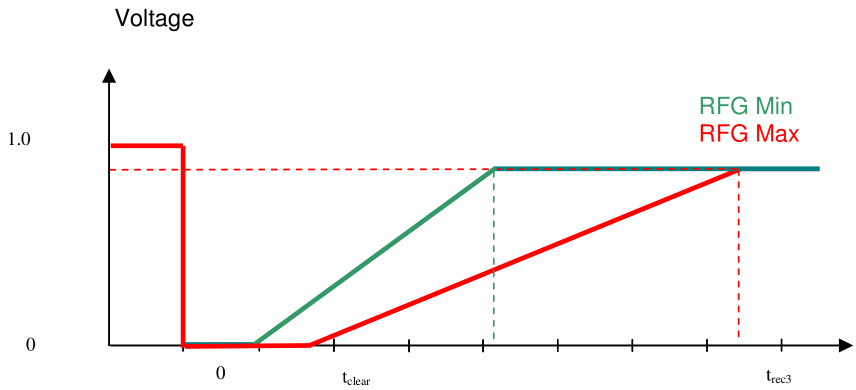

Figure 5.4 Fault Ride Through profile required for **Type D Power Park Modules**. The diagram represents the lower limit of a voltage against time profile by the voltage at the **Connection Point**, expressed by the ratio of its actual value and its nominal value in per unit before, during and after a fault. Uret is the retained voltage at the **Connection Point**. During a fault, tclear is the instant when the fault has been cleared. Urec1, Urec2, trec1, trec2 and trec3 specify certain points of lower limits of Voltage recovery after fault clearance.

(Note:- NGET will need to define the voltage against time profile which will be somewhere between the Green and Red Curves)

Voltage parameters (p.u)		Time parameters (seconds)	
U_{ret}:	0	t_{clear}	0.14 – 0.25
U_{clear}:	U_{ret}	t_{rec1}	t_{clear}
U_{rec1}:	U_{clear}	t_{rec2}	trec1
$U_{rec\ 2}$:	0.85	t_{rec3}	1.5 – 3.0

Table 5.4 Parameters for Figure 5.4 for fault ride through capability of **Type D Power Park Modules**

(ii) During the period of the fault as detailed in CC.6.3.15.6(a)(i) for which the voltage at the **Connection Point** is outside the limits specified in CC.6.1.4, each **Type D Power Park Module** is required to satisfy the additional reactive current injection requirements defined in CC.6.3.15.7.

Comment [A11]: Under the Current GB Grid Code, Active Power Recovery is required within 0.5 seconds for faults upto 140ms and 1 second for faults in excess of 140ms. This will cause a slight issue for the RfG implementation. We can have a dual requirement which states for faults upto 140ms a 0.5 second recovery is required and for faults in excess of 140ms a 1 second recovery is required.

(iii) **NGET** shall define the fault ride through pre-fault and post fault conditions at the **Connection Point** in the **Bilateral Agreement**. This will include details of:-

- conditions for the calculation of the pre-fault minimum short circuit capacity at the **Connection Point**

- conditions for the pre-fault active and **Reactive Power** operating point of the **Power Generating Module** at the **Connection Point** and voltage at the **Connection Point** and

- conditions for the calculation of the post – fault minimum short circuit capacity at the **Connection Point**.

_(iv) **NGET** shall provide upon request to the **Generator**, the pre-fault and post fault conditions to be considered for fault ride through as an outcome of the calculations at the **Connection Point**. This shall include:-

- pre-fault minimum short circuit capacity at each **Connection Point** expressed in MVA.

- pre-fault operating point of the **Power Park Module** expressed in **Active Power** output and **Reactive Power** output at the **Connection Point** and voltage at the **Connection Point**; and

- post fault minimum short circuit capacity at each **Connection Point** expressed in MVA

- alternatively generic values for the above conditions derived from typical cases may be provided by **NGET** or **Network Operator**.

Comment [A12]: In RfG Terms this would be the Power Generating Facility Owner

Comment [A13]: Do we need to make reference to the Relevant Transmission Licensee here.

(v) The **Generator** shall ensure that the under voltage protection at the **Connection Point** shall be set by the **Generator** to the widest possible range so that it does not impinge on the ability of the **Type D Power Park Module** to satisfy the fault ride through requirements defined in CC.6.3.15.7 of the Grid Code unless **NGET** has agreed to any relays which will trip the **Power Park Module**. **Generators** shall ensure the protection schemes and settings for internal electrical faults shall be designed not to jeopardise fault ride through performance.

CC.6.3.15.7 Fast Acting additional reactive current requirements applicable to **Type D Power Park Modules**

(a) Each **Type D Power Park Module** is required to:-

(i) inject fast acting additional reactive current at the **Connection Point** during symmetrical (3 phase) faults and disturbances. Each **Type D Power Park Module** shall be capable of either:

(1) ensuring the supply of additional reactive current at the **Connection Point** according to further specifications by the **Relevant Transmission Licensee** and/or **Relevant Network Operator** in co-ordination with **NGET** of the magnitude of this current, depending on the deviation of the voltage at the **Connection Point** from its nominal value or:

(2) alternatively, measuring voltage deviations at the terminals of the individual units of the **Power Park Module** and providing additional reactive current at the terminals of these units according to further specifications by the **Relevant Transmission Licensee** and/or **Network Operator** in coordination with **NGET** of the magnitude of this current, depending on the deviation of the voltage at unit's terminals from its nominal value.

(ii) In addition each **Type D Power Park Module** (CC.6.3.15.7(a)(i)(1)) or the individual units of the Power Park Module (CC.6.3.15.7(a)(ii)(2)) shall be capable of providing at least 2/3 of the additional reactive current within a time period specified by **NGET** which shall not be less than 10ms. The target value of this additional reactive current defined by CC.6.3.15.7(a)(i)(1) shall be reached with an accuracy of 10% within 60ms from the moment the voltage deviation has occurred as further specified according to CC.6.3.15.7(a)(1).

(iii) The total reactive current contribution shall be not more than 1p.u of the short term dynamic current rating (covering 0.4 seconds) of the **Power Park Module** (CC.6.3.15.7(a)(i)(1)) or the individual units of the **Power Park Module** (CC.6.3.15.7(a)(i)(2)) taking into account the pre-fault reactive current. If additional real current injection is given priority over additional reactive current injection, the total current contribution can be further limited by the real current based on limiting the apparent current (vector addition of real and reactive current) to 1p.u of the short term dynamic rating of the **Power Park Module** (CC.6.3.15.7(a)(i)(1)) or the individual units of the **Power Park Module** (CC.6.3.15.7(a)(i)(2)).

(iv) With regard to fast acting additional reactive current injection in the case of asymmetrical (1-phase or 2-phase) faults the **Network Operator** in coordination with **NGET** shall define the requirements for asymmetrical current injection.

Comment [A14]: All of this text is new to the GB Grid Code. There are a number of sections which are both unclear and also require some internal modelling work to determine the GB Requirements. In view of this, signinificant re-vision to this section of the wording + modelling work will be required to define the requirements. There is however no problem in implenting these types of requirements into the GB Grid Code.

CC.6.3.15.8 Other Requirements

(i) In the case of a **Power Park Module** (comprising of wind-turbine generator units), the requirements in CC.6.3.15.1 to CC.6.3.15.7 do not apply when the **Power Park Module** is operating at less than 5% of its **Rated MW** or during very high wind speed conditions when more than 50% of the wind turbine generator units in a **Power Park Module** have been shut down or disconnected under an emergency shutdown sequence to protect **User's Plant** and **Apparatus**.

(ii) In addition to meeting the conditions specified in CC.6.1.5(b) and CC.6.1.6, each **Type B**, **Type C** or **Type D Non-Synchronous Generating Unit**, or **Type B, Type C** or **Type D Power Park Module** and any constituent **Power Park Unit** thereof will be required to withstand, without tripping, the negative phase sequence loading incurred by clearance of a close-up phase-to-phase fault, by **System Back-Up Protection** on the **Onshore Transmission System** operating at **Supergrid Voltage**.

(iii)

(iv) To avoid unwanted island operation, all **Type B**, **Type C** and **Type D Non-Synchronous Generating Units** in Scotland (and those directly connected to a **Scottish Offshore Transmission System**), **Type B, Type C and Type D Power Park Modules** in Scotland shall be tripped for the following conditions:

(1) **Frequency** above 52Hz for more than 2 seconds

(2) **Frequency** below 47Hz for more than 2 seconds

(3) Voltage as measured at the **Connection Point** or **User System Entry Point** in the case is below 80% for more than 2.5 seconds

(4) Voltage as measured at the **Connection Point** or **User System Entry Point** is above 120% (115% for 275kV) for more than 1 second.

The times in sections (1) and (2) are maximum trip times. Shorter times may be used to protect **Non-Synchronous Generating Units** or **Type B**, **Type C** and **Type D Power Park Modules**.

CONNECTION CONDITIONS APPENDIX 4 - FAULT RIDE THROUGH REQUIREMENTS

CONNECTION CONDITIONS - APPENDIX 4A - FAULT RIDE THROUGH REQUIREMENTS FOR TYPE B AND C SYNCHRONOUS POWER GENERATING MODULES - EXAMPLES

CC.A.4A.1 Scope

Fault ride through is an essential requirement to ensure stable operation of the power system during network disturbances in particular to the maintenance of frequency stability following clearance of a fault.

The fault ride through requirements are based on a voltage against time profile at the **Connection Point** which reflects the worst voltage variation during a fault and after its clearance (retained voltage during a fault and post – fault voltage recovery) which is to be withstood. As defined in CC.6.3.15.1, **Type B** and **Type C Synchronous Power Generating Modules** are required to stay connected to the **System** for voltage deviations above a defined voltage against time curve at the **Connection Point** and in addition shall continue stable operation after the fault on the **System** has been cleared.

This Appendix is designed to provide illustrations by way of examples of CC.6.3.15.1 and further background and illustrations but is not intended to show all possible permutations.

For a fault on the **System** which results in the voltage at the **Connection Point** deviating from nominal, all **Type B** and **Type C Synchronous Power Generating Modules** are required to satisfy the requirements of CC.6.3.15.1 including the requirements of CC.6.3.15.1, Figure 5.1 which is reproduced in this Appendix as Figure CC.A.4A.1

For the avoidance of doubt, there is no requirement for the actual voltage recovery curve to be of the shape of the voltage against time profile shown in figure CC.A.4A.1 but rather it is the boundary against which the **Type B** or **Type C Synchronous Power Generating Module** should remain connected if the transient voltage response following the fault remains above the boundary of Figure CC.A.4.A.1.

Comment [A15]: Note Figure CC.A.4.A.1 shows the ENTSO-E envelope of operation the red being the more onerous case and the green being the least onerous. National Grid (subject to National Governance will need to define a profile between these curves but for the purposes of this example we will leave the two curves in place.

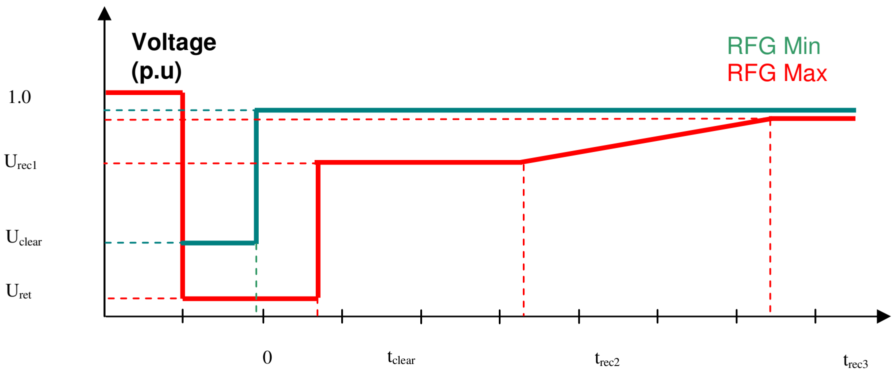

Figure CC.A.4.A.1.

Figures CC.A.4.A.2 (a) (b) and (c) provide examples (superimposed onto the voltage against time curve) to illustrate when a **Type B** or **Type C Synchronous Power Generating Module** should remain connected to the network or when it can be disconnected.

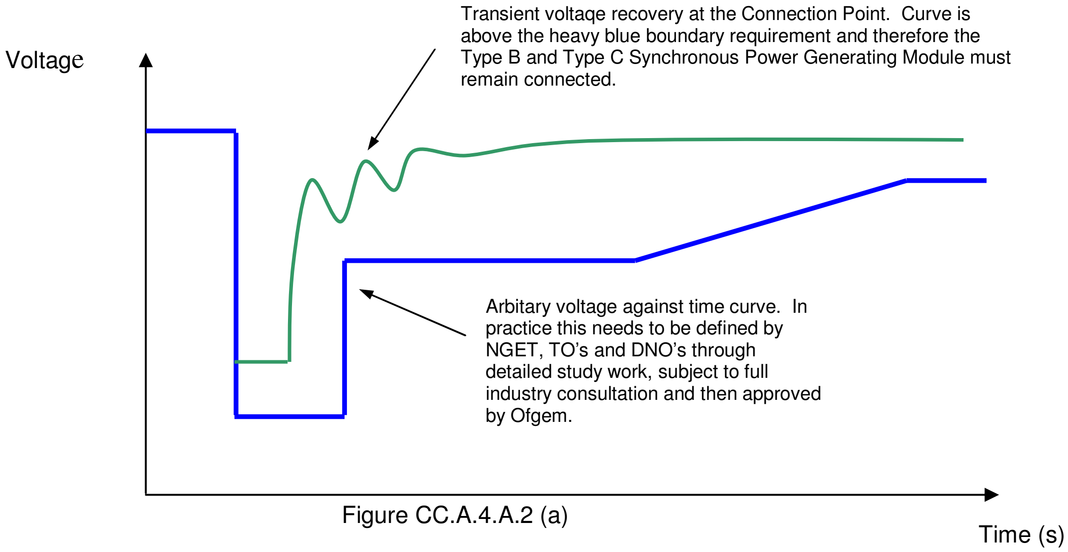

Figure CC.A.4.A.2 (a)

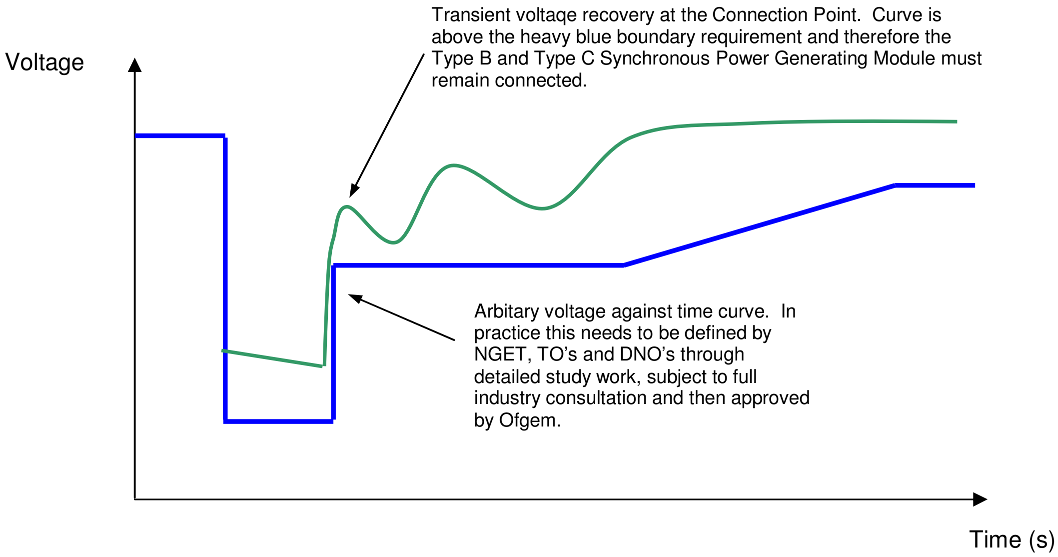

Figure CC.A.4.A.2 (b)

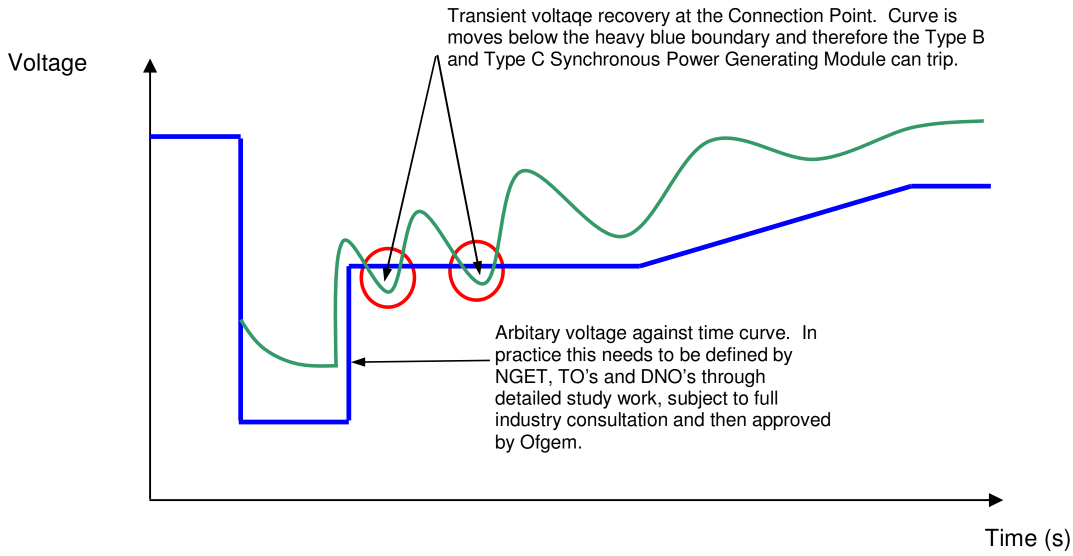

Figure CC.A.4.A.2 (c)

CONNECTION CONDITIONS APPENDIX 4B - FAULT RIDE THROUGH REQUIREMENTS FOR TYPE D SYNCHRONOUS POWER GENERATING MODULES - EXAMPLES

CC.A.4A.2 Scope

Fault ride through is an essential requirement to ensure stable operation of the power system during network disturbances in particular to the maintenance of frequency stability following clearance of a fault.

The fault ride through requirements are based on a voltage against time profile at the **Connection Point** which reflects the worst voltage variation during a fault and after its clearance (retained voltage during a fault and post – fault voltage recovery) which is to be withstood. As defined in CC.6.3.15.2, **Type D Synchronous Power Generating Modules** are required to stay connected to the **System** for voltage deviations above a defined voltage against time curve at the **Connection Point** and in addition shall continue stable operation after the fault on the **System** has been cleared.

This Appendix is designed to provide illustrations by way of examples of CC.6.3.15.2 and further background and illustrations but is not intended to show all possible permutations.

For a fault on the **System** which results in the voltage at the **Connection Point** deviating from nominal, all **Type D Synchronous Power Generating Modules** are required to satisfy the requirements of CC.6.3.15.2 including the requirements of CC.6.3.15.2, Figure 5.2 which is reproduced in this Appendix as Figure CC.A.4B.1

For the avoidance of doubt, there is no requirement for the actual voltage recovery curve to be of the shape of the voltage against time profile shown in figure CC.A.4B.1 but rather it is the boundary against which the **Type D Synchronous Power Generating Module** should remain connected if the transient voltage response following the fault remains above the boundary of Figure CC.A.4.B.1.

Comment [A16]: Note Figure CC.A.4.A.1 shows the ENTSO-E envelope of operation the red being the more onerous case and the green being the least onerous. National Grid (subject to National Governance will need to define a profile between these curves but for the purposes of this example we will leave the two curves in place.

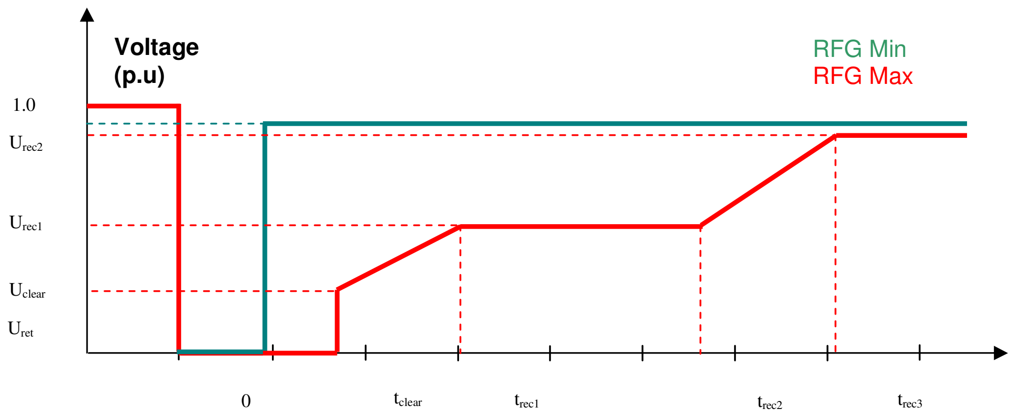

Figure CC.A.4.B.1.

Figures CC.A.4.B.2 (a) (b) and (c) provide examples (superimposed onto the voltage against time curve) to illustrate when a **Type D Synchronous Power Generating Module** should remain connected to the network or when it can be disconnected.

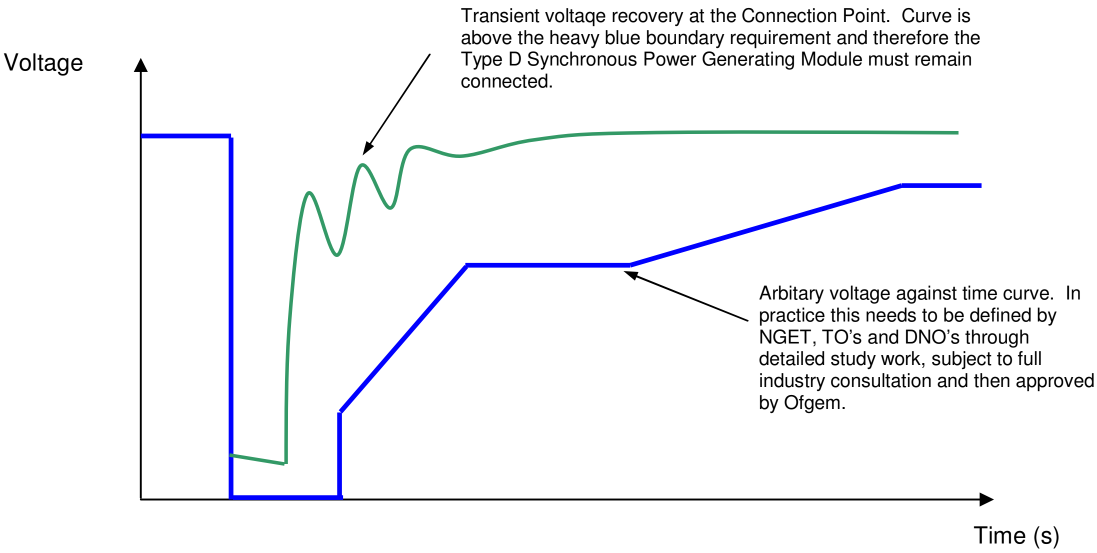

Figure CC.A.4.A.2 (a)

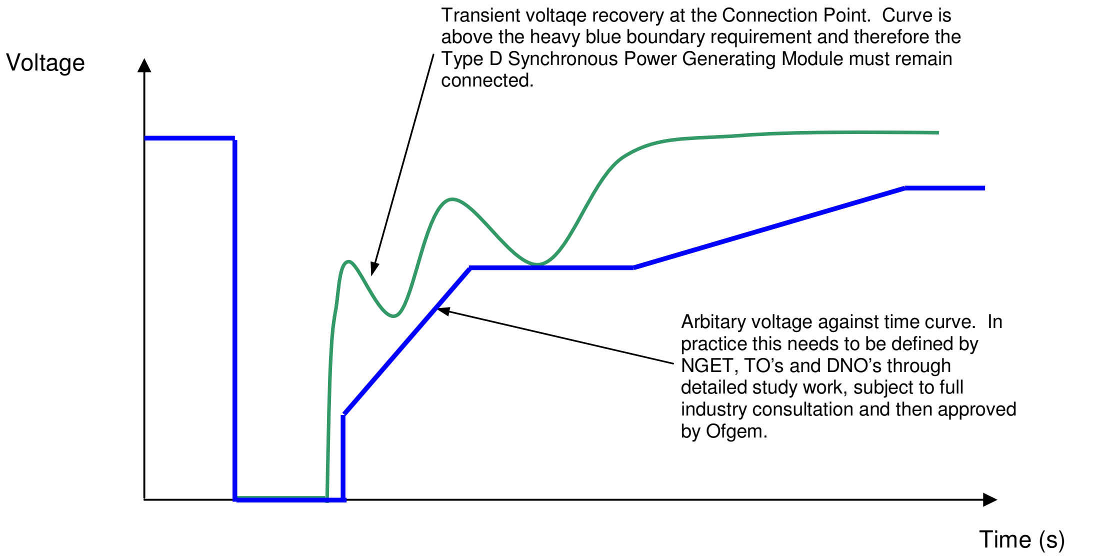

Figure CC.A.4.B.2 (b)

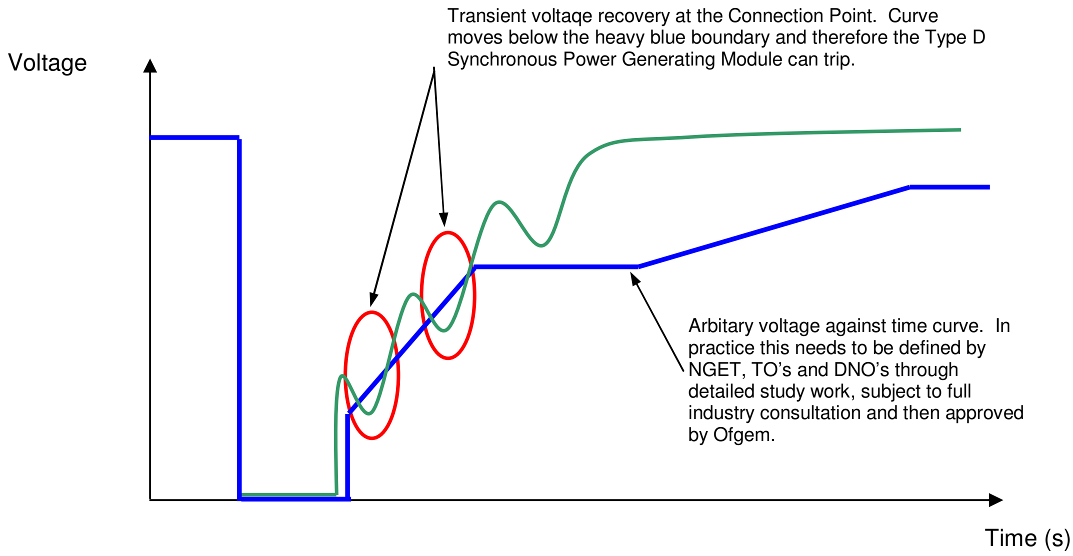

Figure CC.A.4.B.2 (c)

APPENDIX 4C - FAULT RIDE THROUGH REQUIREMENTS FOR TYPE B AND TYPE C POWER PARK MODULES - EXAMPLES

CC.A.4A.3 Scope

Fault ride through is an essential requirement to ensure stable operation of the power system during network disturbances in particular to the maintenance of frequency stability following clearance of a fault.

The fault ride through requirements are based on a voltage against time profile at the **Connection Point** which reflects the worst voltage variation during a fault and after its clearance (retained voltage during a fault and post – fault voltage recovery) which is to be withstood. As defined in CC.6.3.15.3, **Type B** and **Type C Power Park Modules** are required to stay connected to the **System** for voltage deviations above a defined voltage against time curve at the **Connection Point** and in addition shall continue stable operation after the fault on the **System** has been cleared.

This Appendix is designed to provide illustrations by way of examples of CC.6.3.15.2 and further background and illustrations but is not intended to show all possible permutations.

For a fault on the **System** which results in the voltage at the **Connection Point** deviating from nominal, all **Type B and Type C Power Park Modules** are required to satisfy the requirements of CC.6.3.15.3 including the requirements of CC.6.3.15.3, Figure 5.2 which is reproduced in this Appendix as Figure CC.A.4C.1

For the avoidance of doubt, there is no requirement for the actual voltage recovery curve to be of the shape of the voltage against time profile shown in figure CC.A.4C.1 but rather it is the boundary against which the **Type B and Type C Power Park Module** should remain connected if the transient voltage response following the fault remains above the boundary of Figure CC.A.4.C.1.

Comment [A17]: Note Figure CC.A.4.A.1 shows the ENTSO-E envelope of operation the red being the more onerous case and the green being the least onerous. National Grid (subject to National Governance will need to define a profile between these curves but for the purposes of this example we will leave the two curves in place.

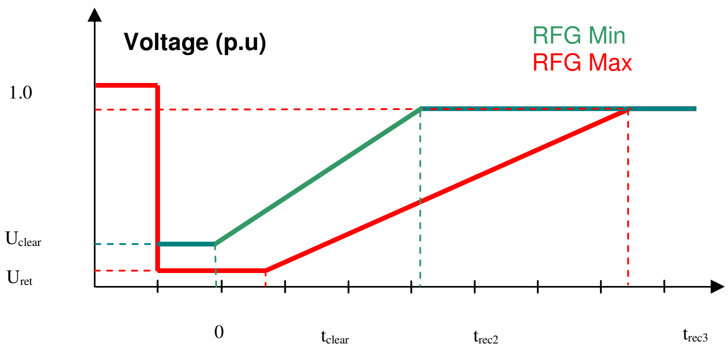

Figure CC.A.4.C.1.

Figures CC.A.4..2 (a) (b) and (c) provide examples (superimposed onto the voltage against time curve) to illustrate when a **Type B** or **Type C Power Park Module** should remain connected to the network or when it can be disconnected.

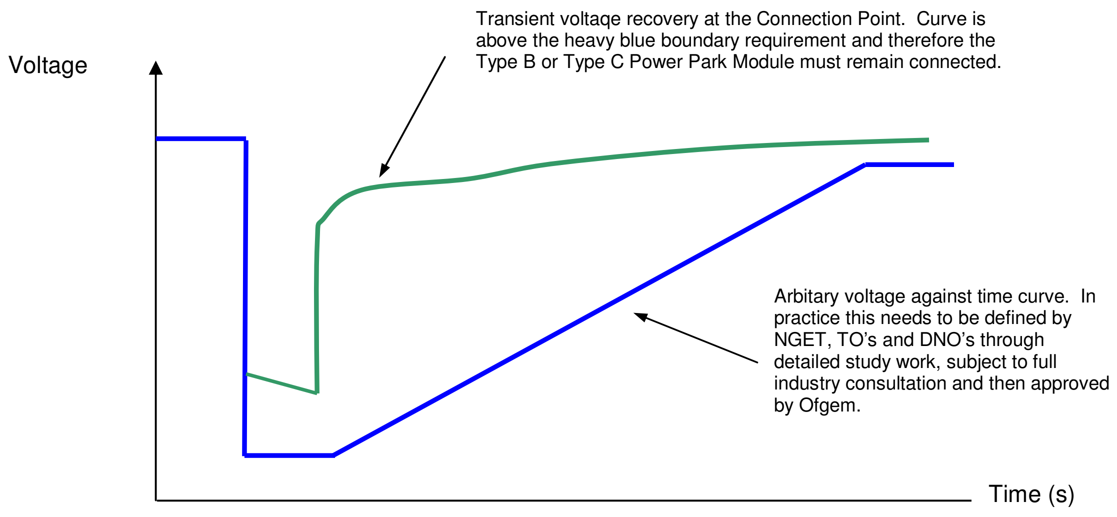

Figure CC.A.4.C.2 (a)

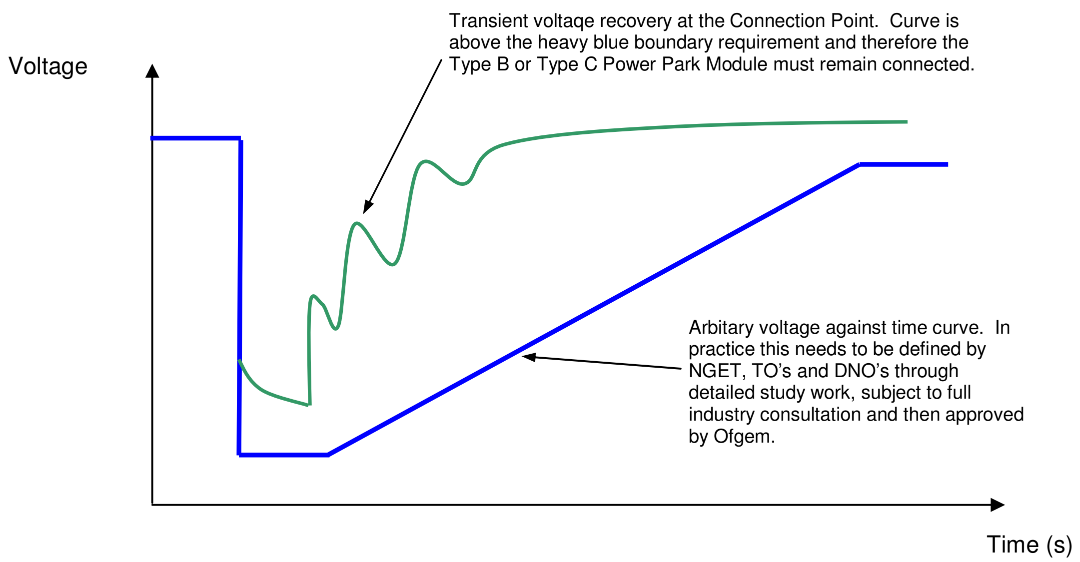

Figure CC.A.4.C.2 (b)

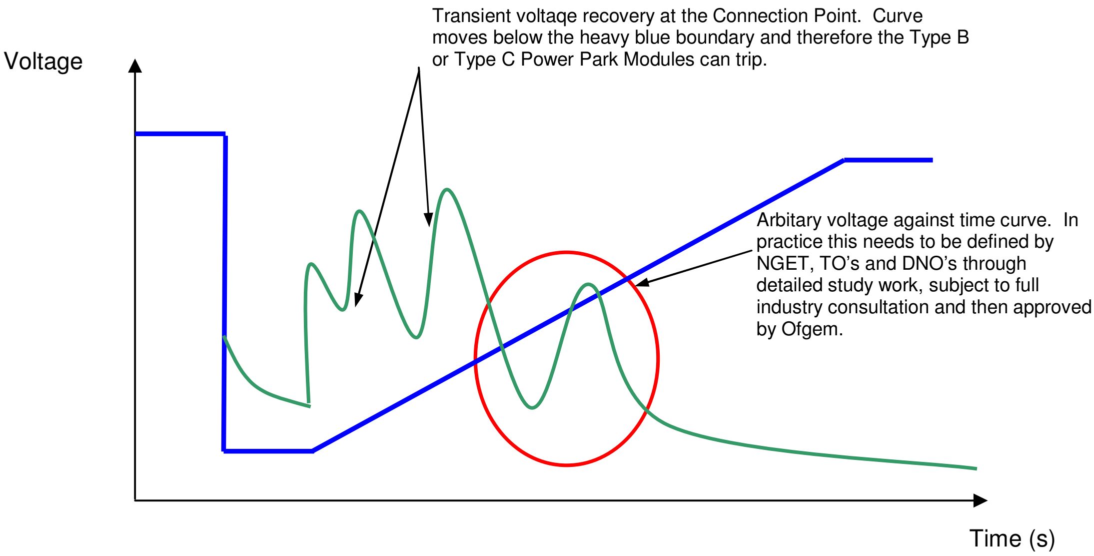

Figure CC.A.4.C.2 (c)

CONNECITON CONDITIONS APPENDIX 4D - FAULT RIDE THROUGH REQUIREMENTS FOR TYPE D POWER PARK MODULES - EXAMPLES

CC.A.4A.4 Scope

Fault ride through is an essential requirement to ensure stable operation of the power system during network disturbances in particular to the maintenance of frequency stability following clearance of a fault.

The fault ride through requirements are based on a voltage against time profile at the **Connection Point** which reflects the worst voltage variation during a fault and after its clearance (retained voltage during a fault and post – fault voltage recovery) which is to be withstood. As defined in CC.6.3.15.6, **Type D Power Park Modules** are required to stay connected to the **System** for voltage deviations above a defined voltage against time curve at the **Connection Point** and in addition shall continue stable operation after the fault on the **System** has been cleared.

This Appendix is designed to provide illustrations by way of examples of CC.6.3.15.6 and further background and illustrations but is not intended to show all possible permutations.

For a fault on the **System** which results in the voltage at the **Connection Point** deviating from nominal, all **Type D Power Park Modules** are required to satisfy the requirements of CC.6.3.15.6 including the requirements of CC.6.3.15.6, Figure 5.4 which is reproduced in this Appendix as Figure CC.A.4D.1

For the avoidance of doubt, there is no requirement for the actual voltage recovery curve to be of the shape of the voltage against time profile shown in figure CC.A.4D.1 but rather it is the boundary against which the **Type D Power Park Module** should remain connected if the transient voltage response following the fault remains above the boundary of Figure CC.A.4.D.1.

Comment [A18]: Note Figure CC.A.4.A.1 shows the ENTSO-E envelope of operation the red being the more onerous case and the green being the least onerous. National Grid (subject to National Governance will need to define a profile between these curves but for the purposes of this example we will leave the two curves in place.

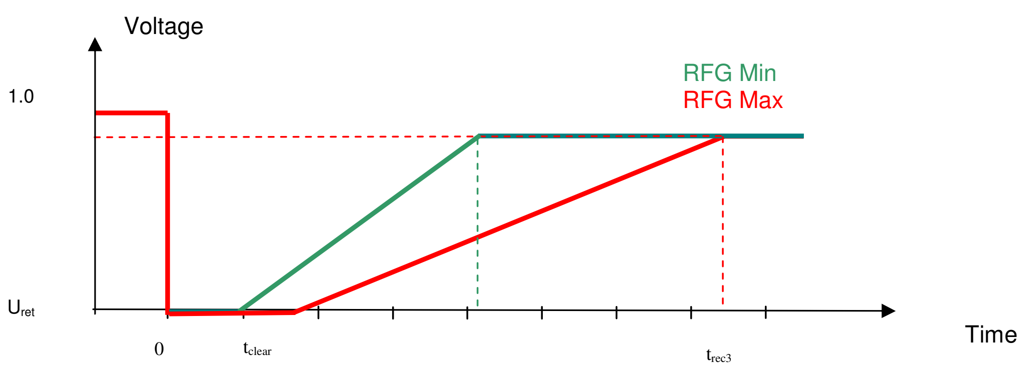

Figure CC.A.4.D.1.

Figures CC.A.4.D.2 (a) (b) and (c) provide examples (superimposed onto the voltage against time curve) to illustrate when a **Type D Power Park Module** should remain connected to the network or when it can be disconnected.

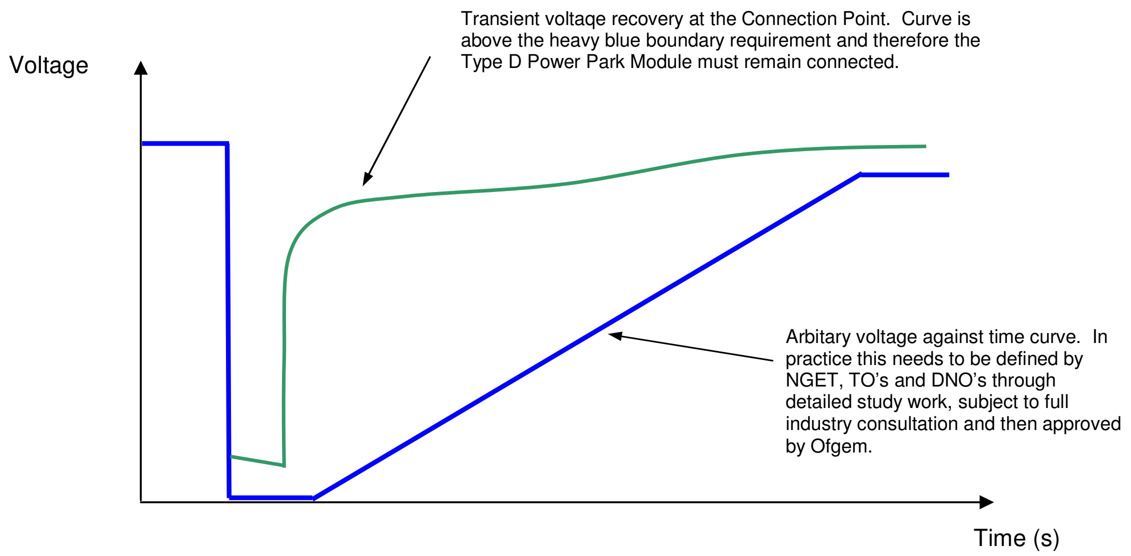

Figure CC.A.4.D.2 (a)

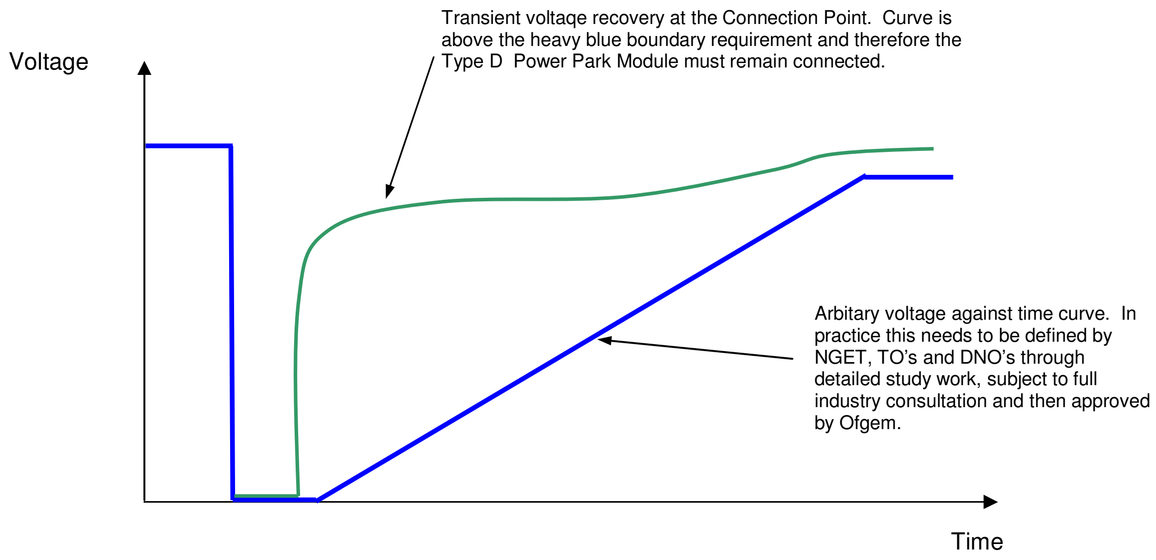

Figure CC.A.4.D.2 (b)

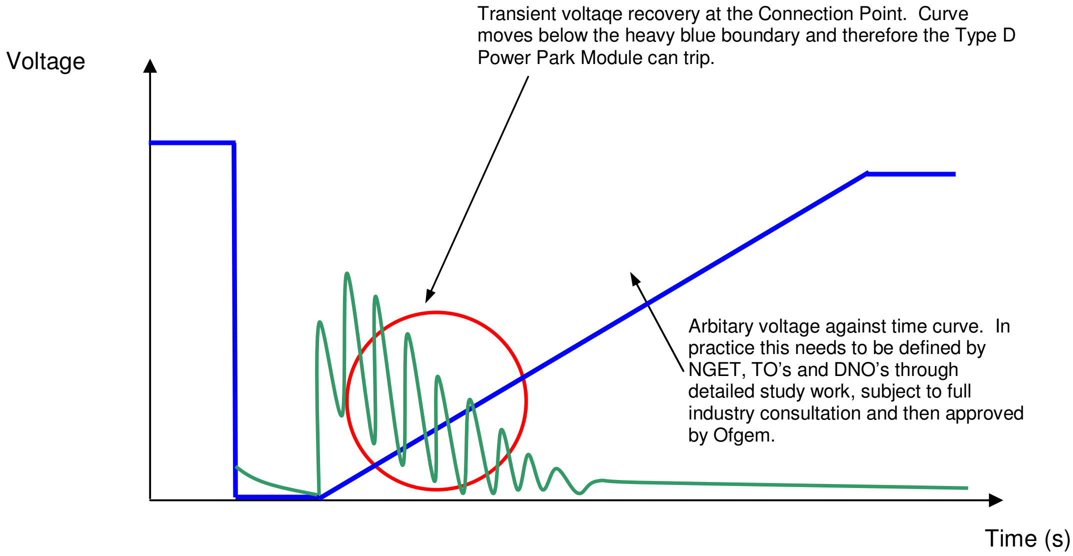

Figure CC.A.4.D.2 (c)