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GC0111: Fast Fault Current Injection Specification Text



Workgroup 1

4 July 2018

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Agenda

1. Background & Scope of Workgroup
2. Presentation for Workgroup
3. Workgroup Discussions
4. Legal text (as circulated)
5. Proposer Impact and Assessment
6. Implementation
7. Next steps

Background

- Modification was raised by Electricity North West in April 2018. Original proposal can be accessed via the following link:

  https://www.nationalgrid.com/uk/electricity/codes/grid-code/modifications/gc0111-fast-fault-current-injection-specification-text

- Modification tabled at April GCRP and Panel agreed that the Self-Governance Criteria was met on the basis that there is currently no known material effect
- The modification is to be developed by a Workgroup. See next slide for scope.
- Nominations window 4 May – 21 May. 15 responses received for Workgroup membership or observer status. There are 10 voting Workgroup members.

Scope of Workgroup

- *Implementation and costs;*
- *Review draft legal text;*
- *Consider whether any further Industry experts or stakeholders should be invited to participate within the Workgroup to ensure that all potentially affected stakeholders have the opportunity to be represented in the Workgroup. Demonstrate what has been done to cover this clearly in the report*
- *Consider materiality of change*
- *Consider whether Workgroup consultations required*
- *Review the trigger voltage and FRT requirements and whether compatible*

GC0111
RfG Clarifications to Fast Fault Current Injection

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National Grid – Network Capability
July 2018

Summary

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- Background to the RfG Fast Fault Current Requirements
- Summary of the RfG Fast Fault Current Requirements
- Areas of concern raised by Stakeholders
- Proposed clarifications
- Examples
- Summary
- Next Steps

Background to RfG Fast Fault Current Injection Requirements

- Addressed through Consultation G0100
  - https://www.nationalgrid.com/sites/default/files/documents/Final%20Workgroup%20consultation_0.pdf
- Three options Proposed
  - Option 1 - Enhanced Converter Control (Virtual Synchronous Machine capability) – Rejected – Covered under a new Expert Working Group
  - Option 2 – Classical Phase Locked Loop (PLL) type control with a 1.25 pu ceiling reactive current – rejected
  - Option 3 – Classical Phase Locked Loop (PLL) type control with a 1.0 pu ceiling reactive current – Accepted
- Applies only to Power Park Modules and HVDC Systems – Synchronous Generation is excluded from these requirements as it already has a natural capability to provide high levels of fault current

High level Summary of the FFCI Requirements (Option 3)

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Requirement (RfG)	Specification (GB Requirement)
Point of Fast Fault current injection	Connection Point of Power Park Module
How and when voltage is to be determined as well as the end of the voltage deviation	Each time the voltage at the Connection Point drops below 0.9 pu Blocking permitted on fault clearance
The characteristics of the fast fault current, including the time domain for measuring the voltage deviation and fast fault current from which current and voltage may be measured differently form the method specified in (RfG) Article 2 – definition of Fast Fault Current	Each Power Park Module shall be capable of generating maximum Reactive current during the period of the fault without exceeding the transient rating of the Power Park Module. The PLL needs to be disabled in order to maintain the same phase reference
The timing and accuracy of the fast fault current, which may include several stages during a fault and after its clearance	Generator to provide a continuous time trace of reactive current injection before during and after the fault, which demonstrates an acceptable degree of injection within the time period 20-60ms
When post fault active power recovery begins based on a voltage criterion	Active Power Recovery to commence on fault clearance (ie voltage above 0.9 pu, but less than 1.05 pu)
Maximum allowed time for active power recovery	Active Power to be restored within 0.5 seconds of fault clearance (ie voltage above 0.9 pu)
Magnitude and accuracy for active power recovery	Active Power to be restored to 90% of its pre-fault value. 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 Energy was constant and the oscillations are adequately damped.

RfG Definition of Fast Fault Current (Article 2)

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- “Means a current injected by a Power Park Module or HVDC System during and after a voltage deviation caused by an electrical fault with the aim of identifying a fault by network protection systems at the initial stage of the fault, supporting system voltage retention at a later stage of the fault and system voltage restoration after fault clearance”

FFCI Figure ECC.16.3.16(a)

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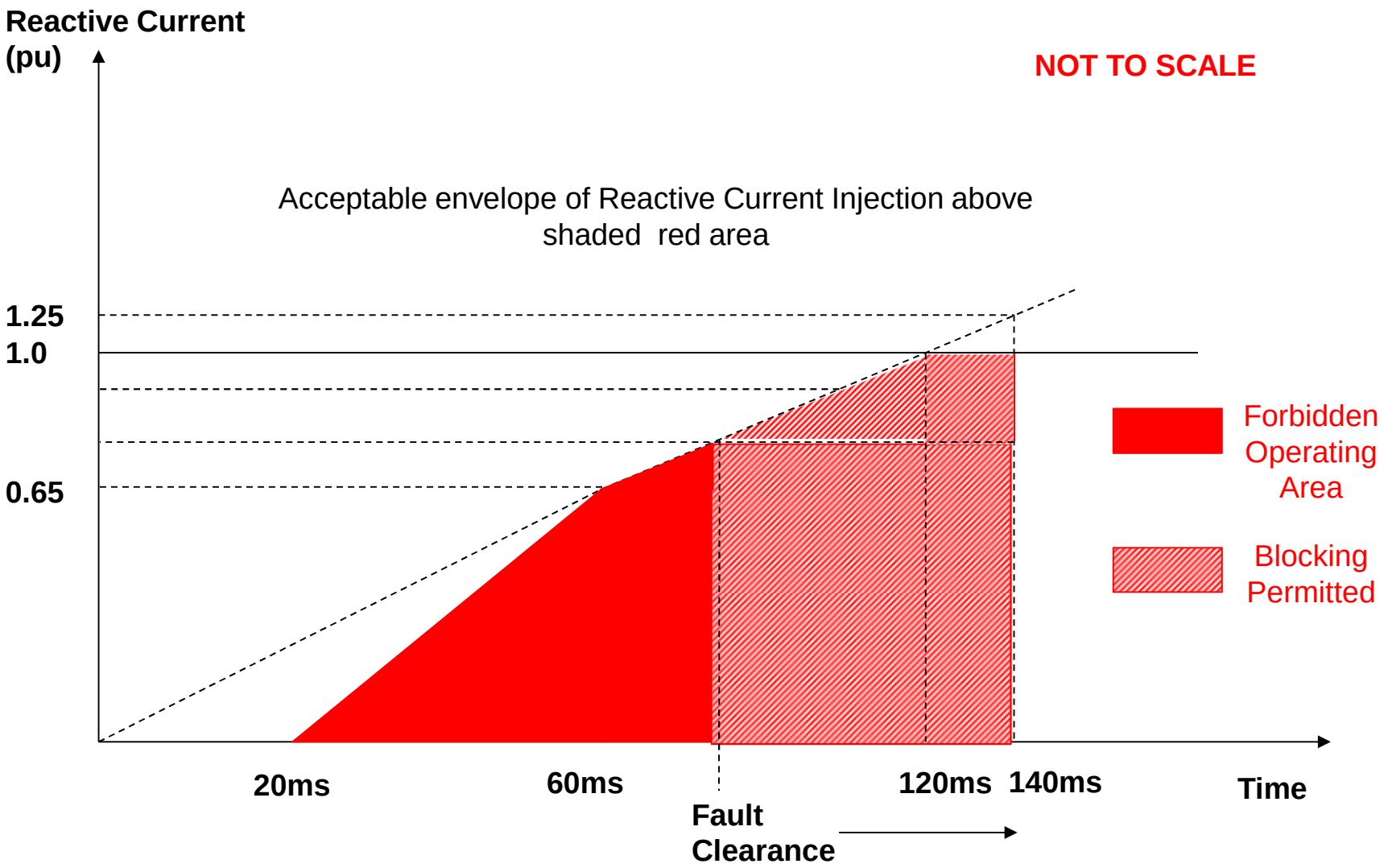
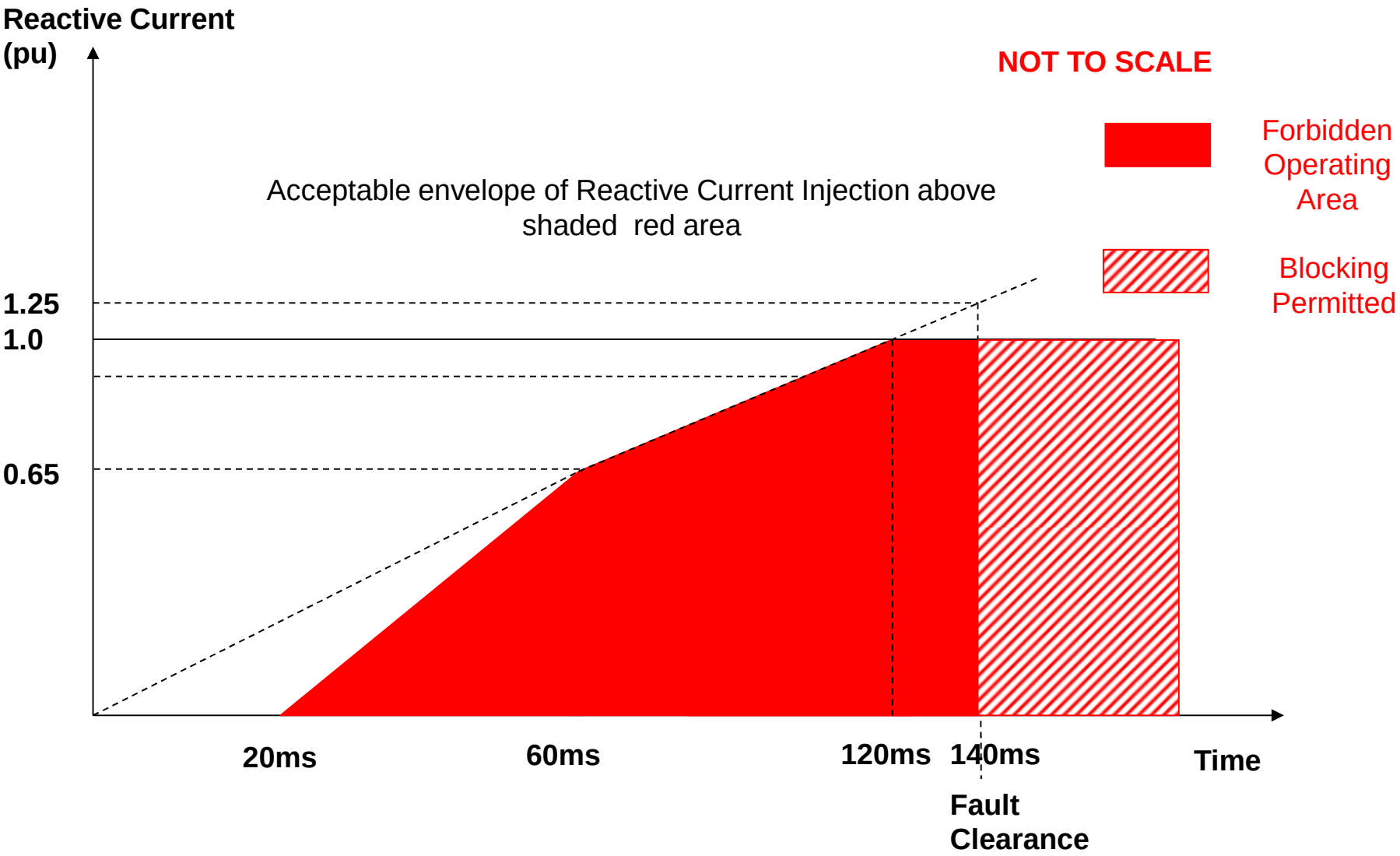


FFCI Figure ECC.16.3.16(b)



Key Features of the FFCI Requirements

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- Requirement for Reactive Current Injection to remain above the shaded area (see slides 5 and 6)
- Blocking permitted on fault clearance to prevent the risk of transient over voltages
- Reactive current injected from each Power Park Module or HVDC Equipment shall be injected in proportion and remain in phase to the change in System Voltage at the Connection Point during the period of the fault
- Generators to state their repeated ability to supply fast fault current to the system each time the voltage at the connection point falls below the nominal levels.
- NGET will accept demonstration of compliance at the Power Park Unit Terminals rather than at the Connection Point where it is not practical to do so
- Example contained in Appendix 4EC

The Defect

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- Following the final GC0100 consultation, no comments were received in respect of FFCI though a number of comments were received following the G99 and Distribution Code Consultation
- ECC.6.3.16.1.2 refers to reactive current, implying the current is always in quadrature with the voltage. This also states the reactive current will be in proportion to the retained voltage
- ECC.6.3.16.1.4 states that the reactive current injected shall be in proportion and in phase with the change in System Voltage at the Connection Point
- A number of questions have been raised in relation to the base quantities and how this relates to rating
- Theses issues are confusing and it is recognised that clarity is required
- Figures ECC.6.3.16(a) and (b) show the reactive current against time but do not show retained voltage
- Further clarification is required to the Example in Appendix 4EC

FFCI – System Requirements

- National Grid agree with these comments and fully support the need to clarify the requirements
- There is a fundamental relationship between Fast Fault Current Injection and Fault Ride Through
- Under the GB Grid Code, the fault ride through requirements are segregated into two parts (faults up to 140ms in duration and voltage dips in excess of 140ms)
- For faults up to 140ms, there is a requirement to prioritise reactive current injection in order to maximise the retained voltage with 90% of the pre-fault Active Power being restored within 500ms of fault clearance to guard against frequency collapse
- For voltage dips in excess of 140ms, there is a requirement to ensure Active Power is retained in proportion to retained voltage – this is required to ensure a degree of reactive support but equally ensure that there is a proportion of real power available to prevent rapid frequency collapse with 90% of the pre fault Active Power being restored within 1 second of restoration of the voltage to nominal levels
- During faults and voltage dips, we would not expect the rating of the Power Park Module or HVDC Converter to be exceeded - hence there is no requirement for enhanced converter ratings.
- These principles already existed in the GB Grid Code pre RfG. RfG has simply required more detail around these requirements – in particular how the reactive current injection should vary with time under fault conditions

The Solution

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- Redraft the Grid Code to address the defect including:-
  - Clearly define the maximum current rating and confirm that the transient rating of the Power Park Module should not be exceeded under fault conditions.
  - Locus diagram included showing relationship between real and reactive current.
  - For faults up to 140ms in duration define that priority should be given to reactive current as soon as the voltage dips below the minimum levels specified in ECC.6.1.4 (ie the reactive current injected should be above the minimum requirement shown in Figures ECC.16.3.16(a) and (b) (ie slides 6 and 7 above)
  - Remove references to “reactive current injected shall be in proportion and in phase with the change in System Voltage at the Connection Point
  - Appendix 4EC has been removed as the examples are considered to be misleading. A number of examples however have been included in this presentation.
  - The requirements for Active Power recovery (restoration of 90% of the Active Power within 500ms of restoration of the voltage at the Connection Point to the minimum levels specified in ECC.6.3.15.8(vii)) remain unchanged.
  - The requirements for voltage dips in excess of 140ms (as detailed in ECC.6.3.15.9) remain unchanged.

Active / Reactive Current Circle Diagram

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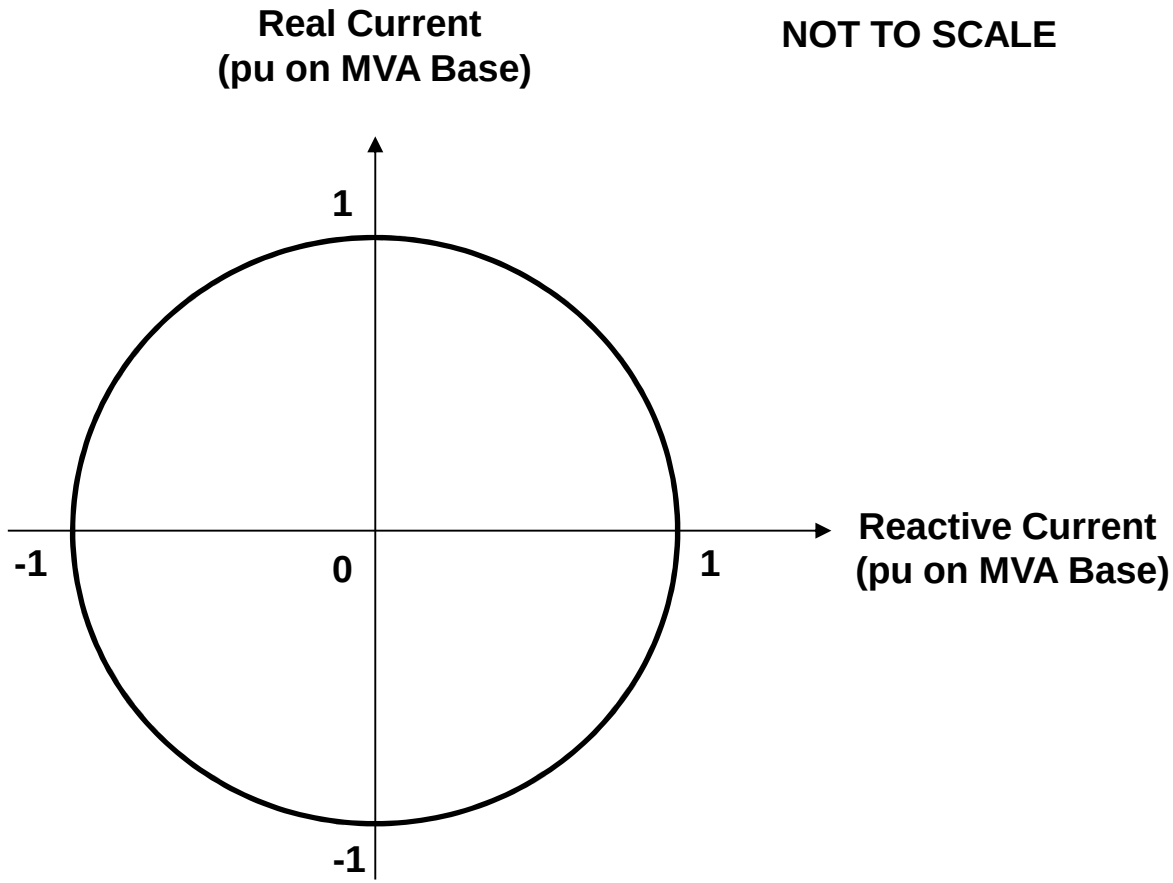
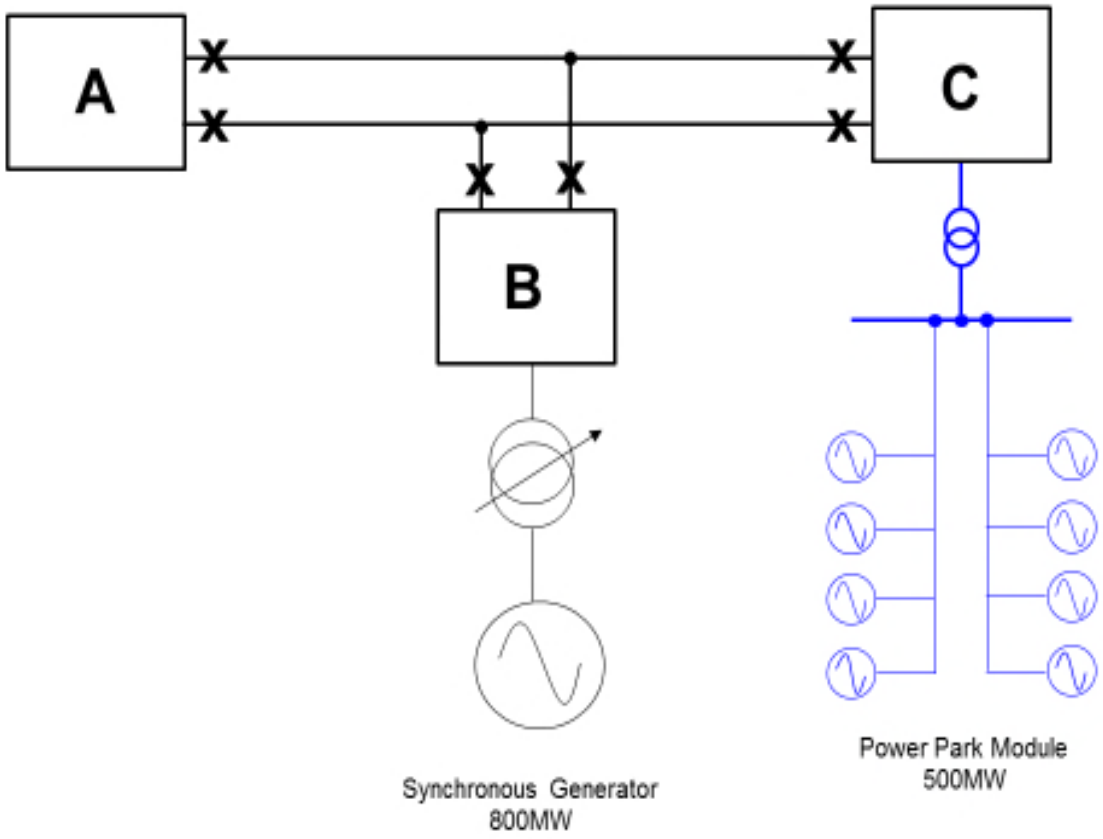
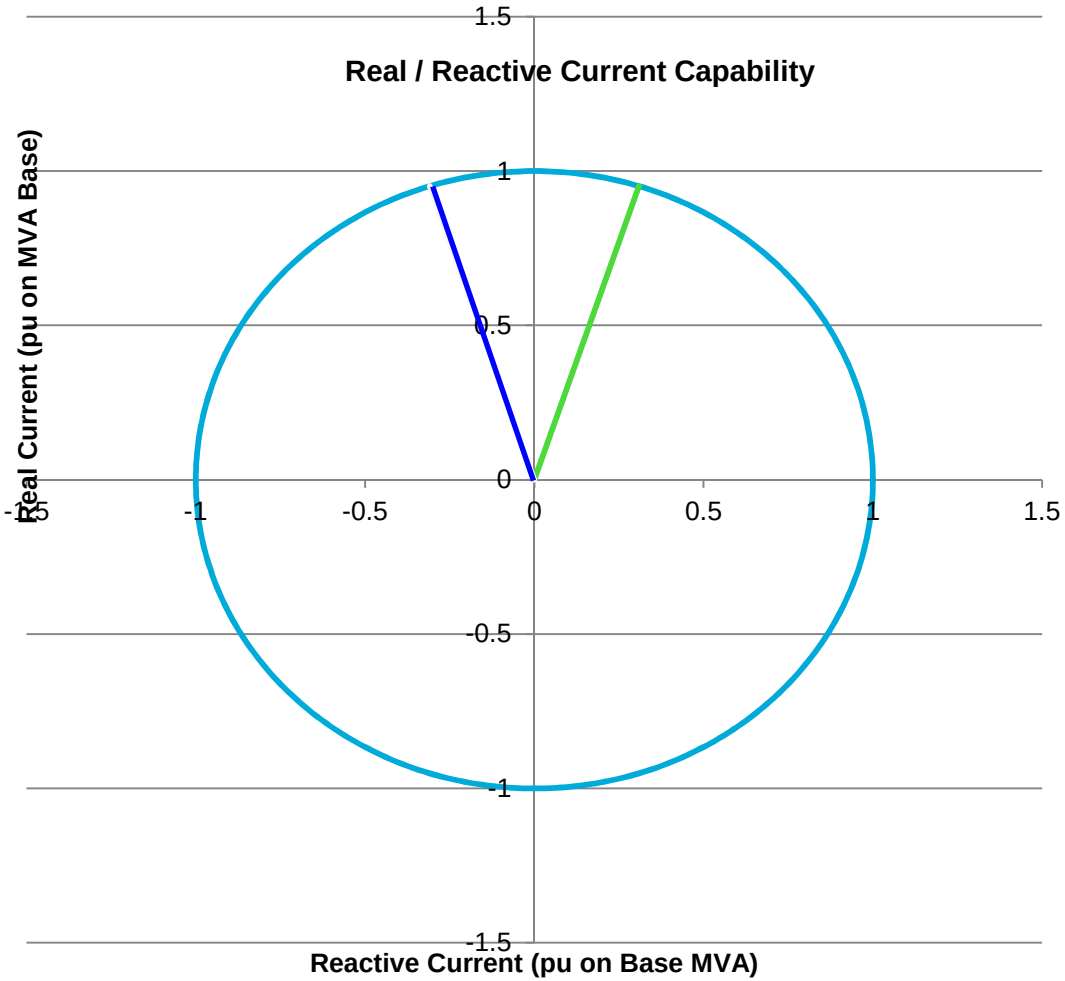


NOTE:- 1 pu current is the rated current of the Power Park Module or HVDC Equipment when operating at full MW output and full leading or Lagging MVAr capability (eg for a 100MW Power Park Module Rated Current would be obtained when the Power Park Module is supplying 100MW and 0.95 Power Factor lead or 0.95 Power Factor lag at the Connection Point)

Example 1 – Pre Fault Condition

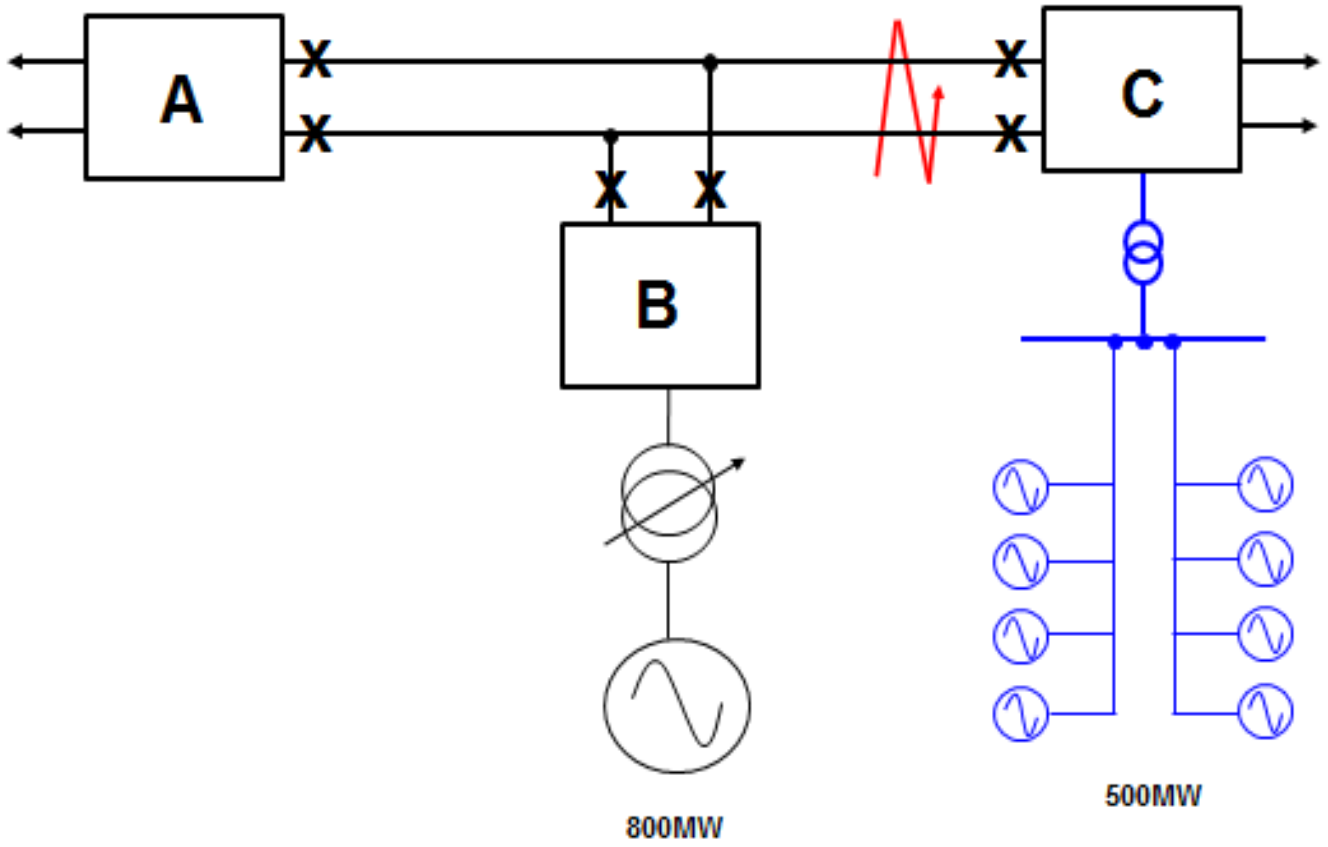


Example 1 – Pre Fault Vector Diagram

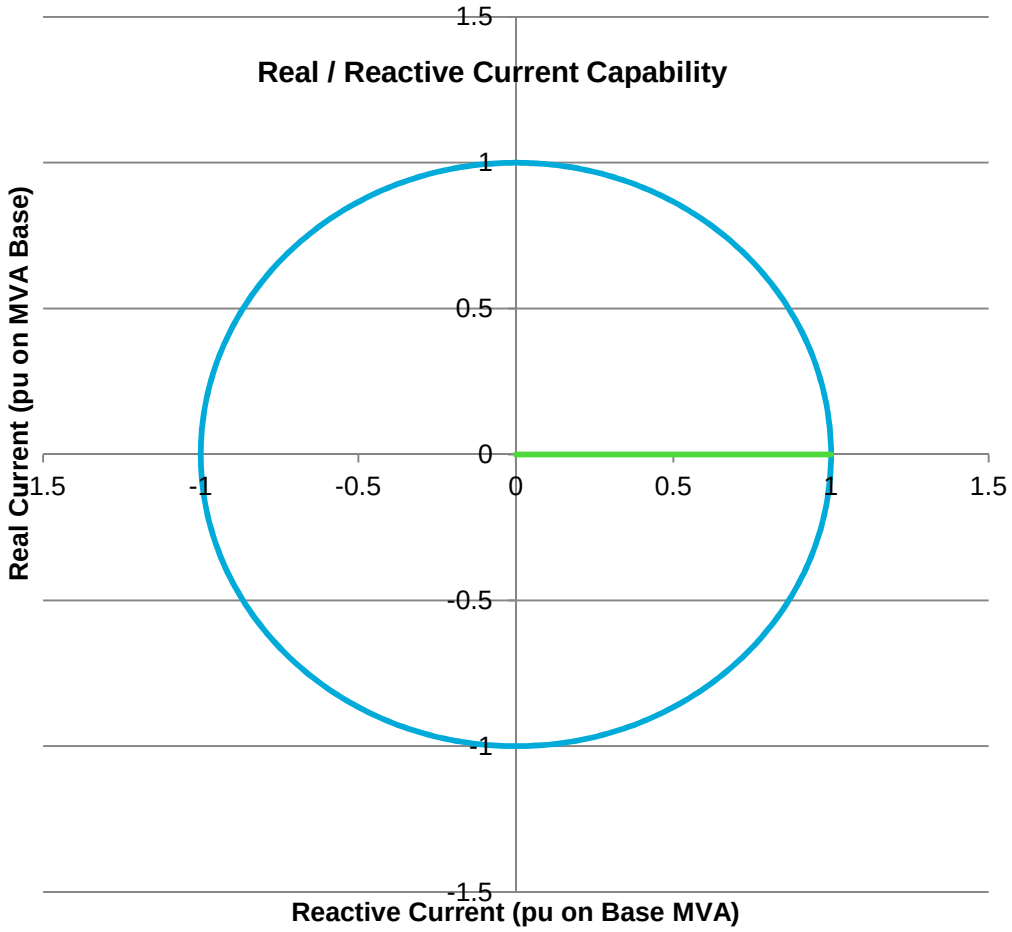


NOTE:- 1 pu current is the rated current of the Power Park Module or HVDC Equipment when operating at full MW output and full leading or Lagging MVAr capability

Example 1 – Close up fault adjacent to Substation C

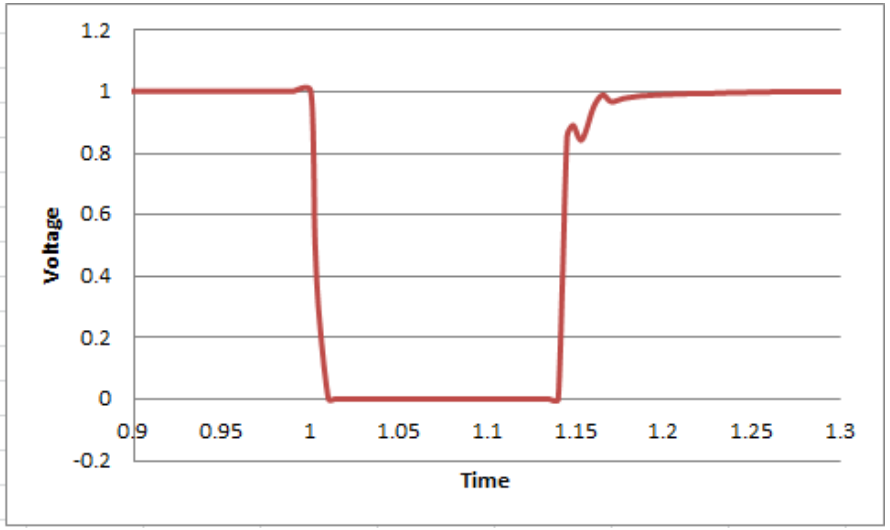


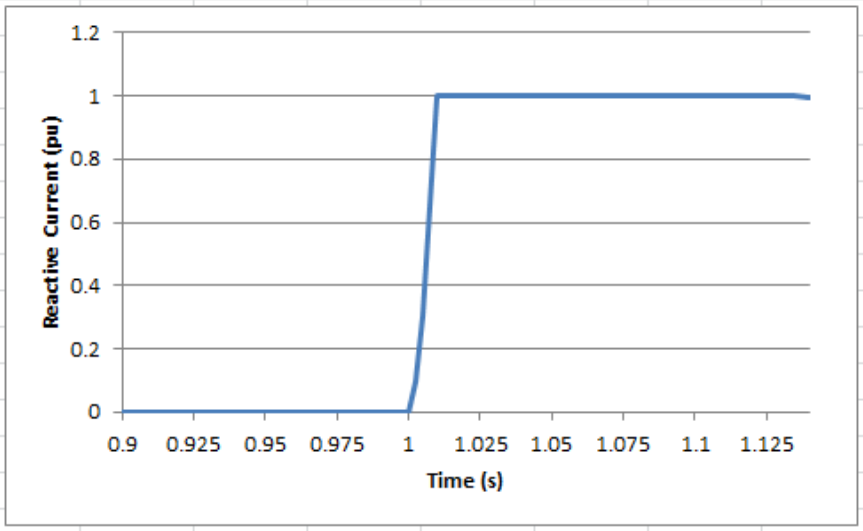
Example 1 – Faulted Case Vector Diagram



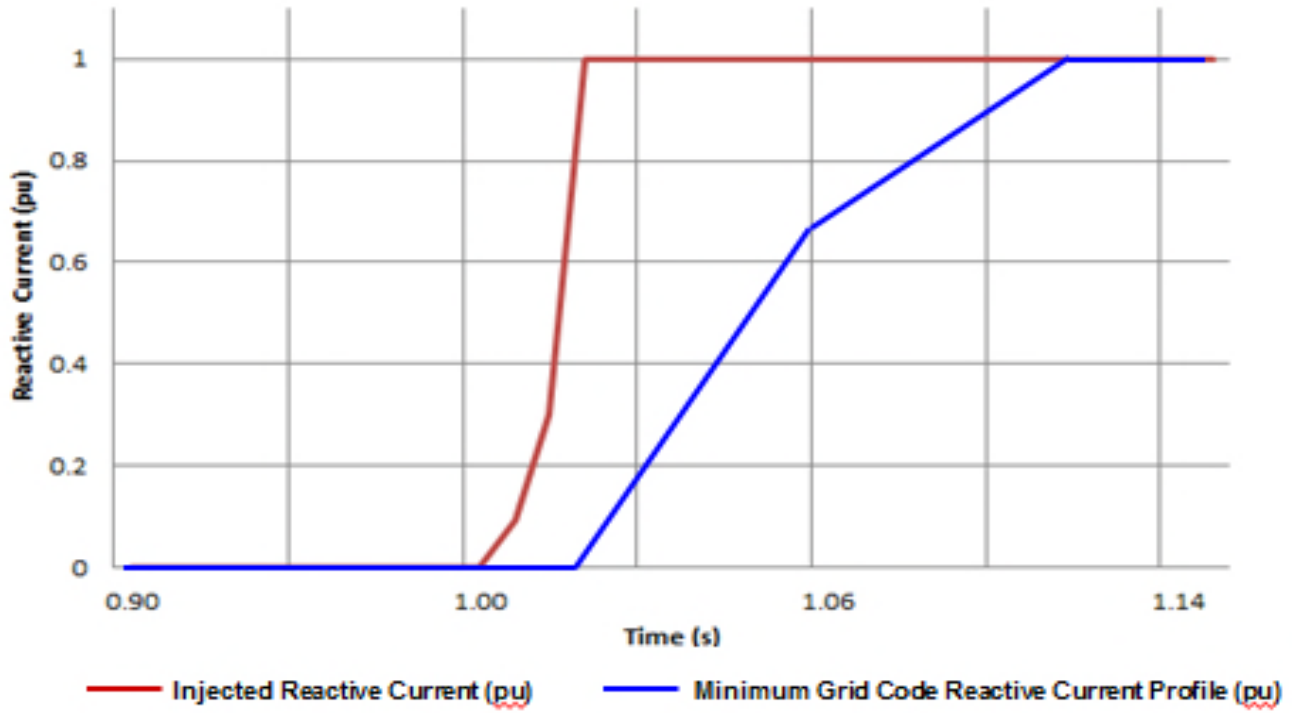
NOTE:- 1 pu current is the rated current of the Power Park Module or HVDC Equipment when operating at full MW output and full leading or Lagging MVAr capability

Example 1 – Close up fault adjacent to Substation C – Voltage / Current Traces



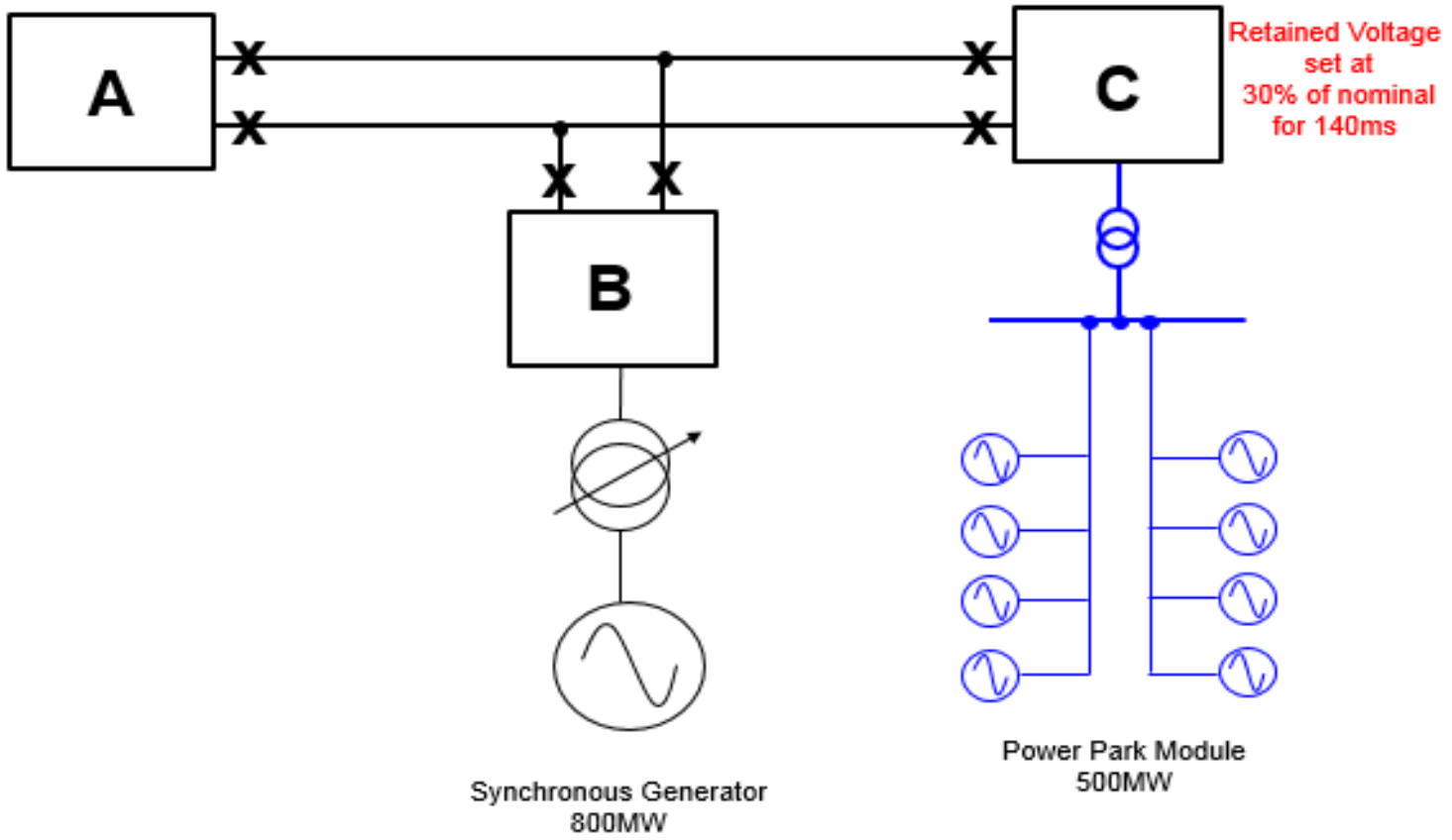


Example 1 – Comparison against ECC.6.3.16 requirement

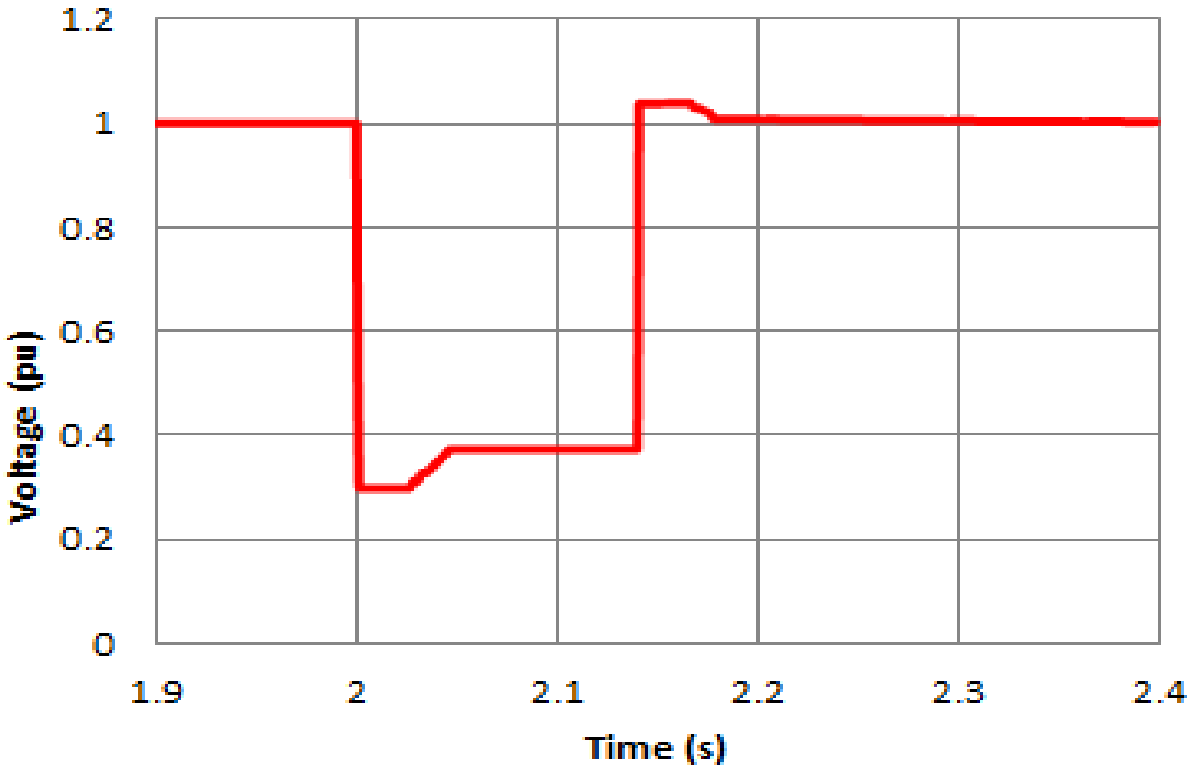


NOTE:- The brown line in the above figure (Injected Reactive Current) is a typical / expected response. For compliance purposes, the injected reactive current need only be above the minimum Grid Code reactive current injection requirement and not the same as the brown line which is shown above for illustrative purposes only.

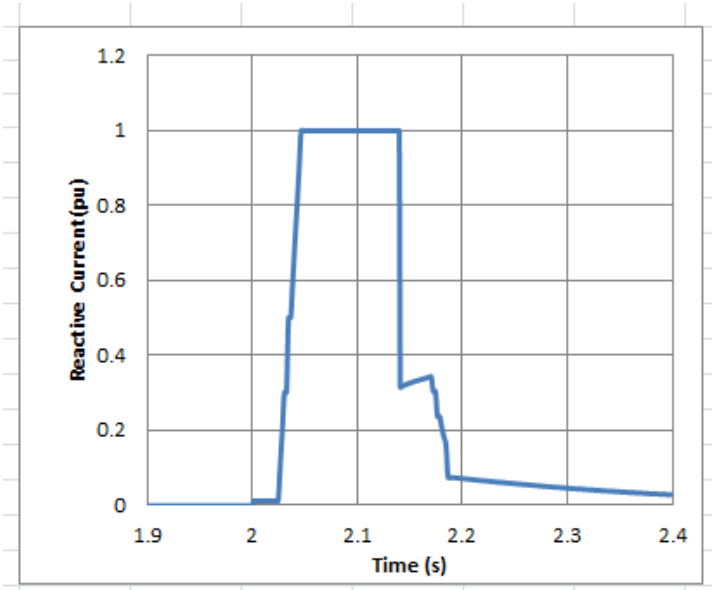
Example 2 – Faulted Condition

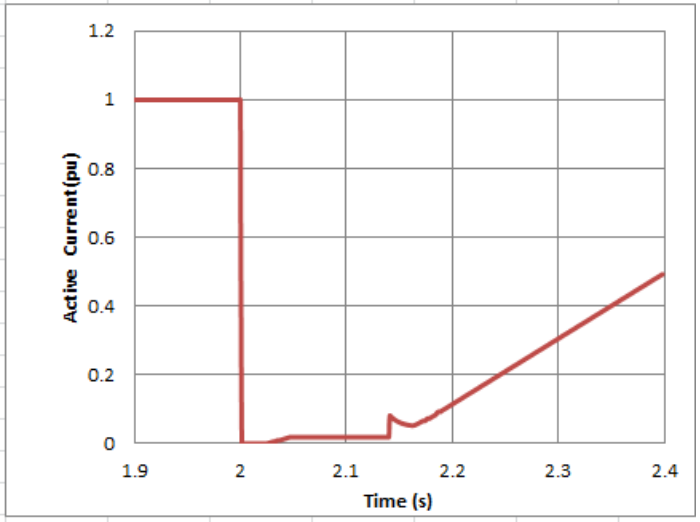


Example 2 – Voltage depression

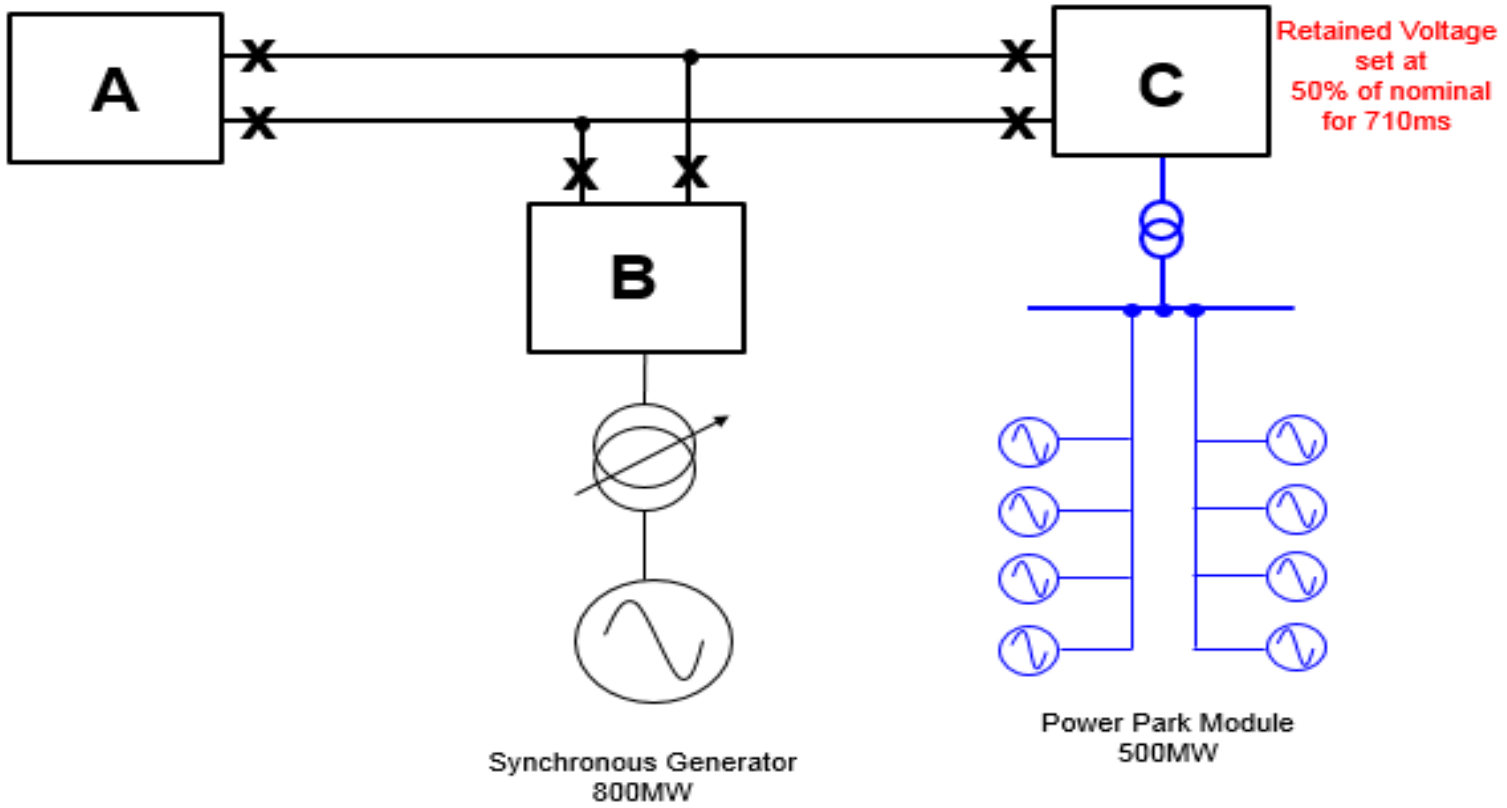


Example 2 – Traces of Active and Reactive Current

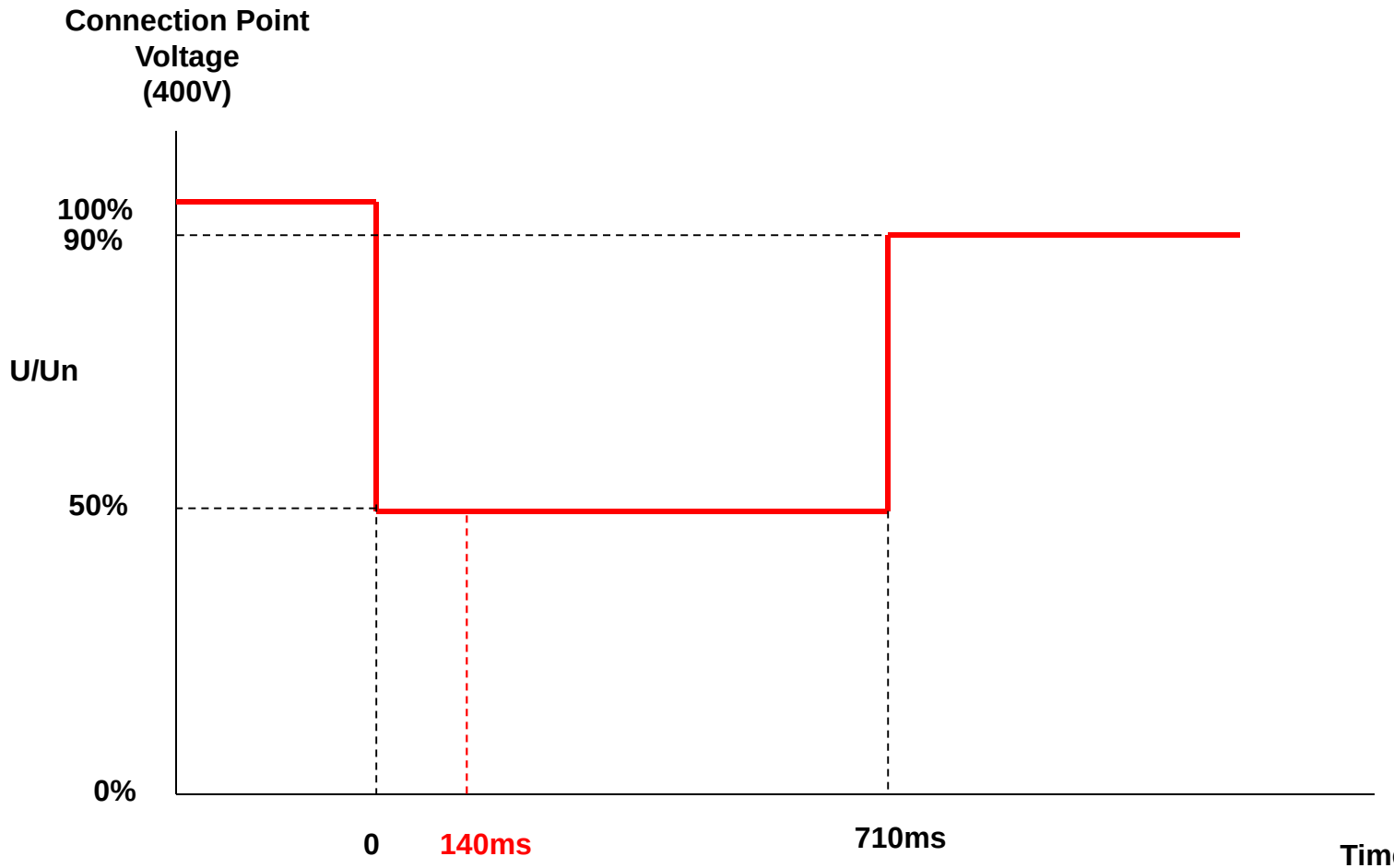




Example 3 – Retained Voltage set at 50% for 710ms

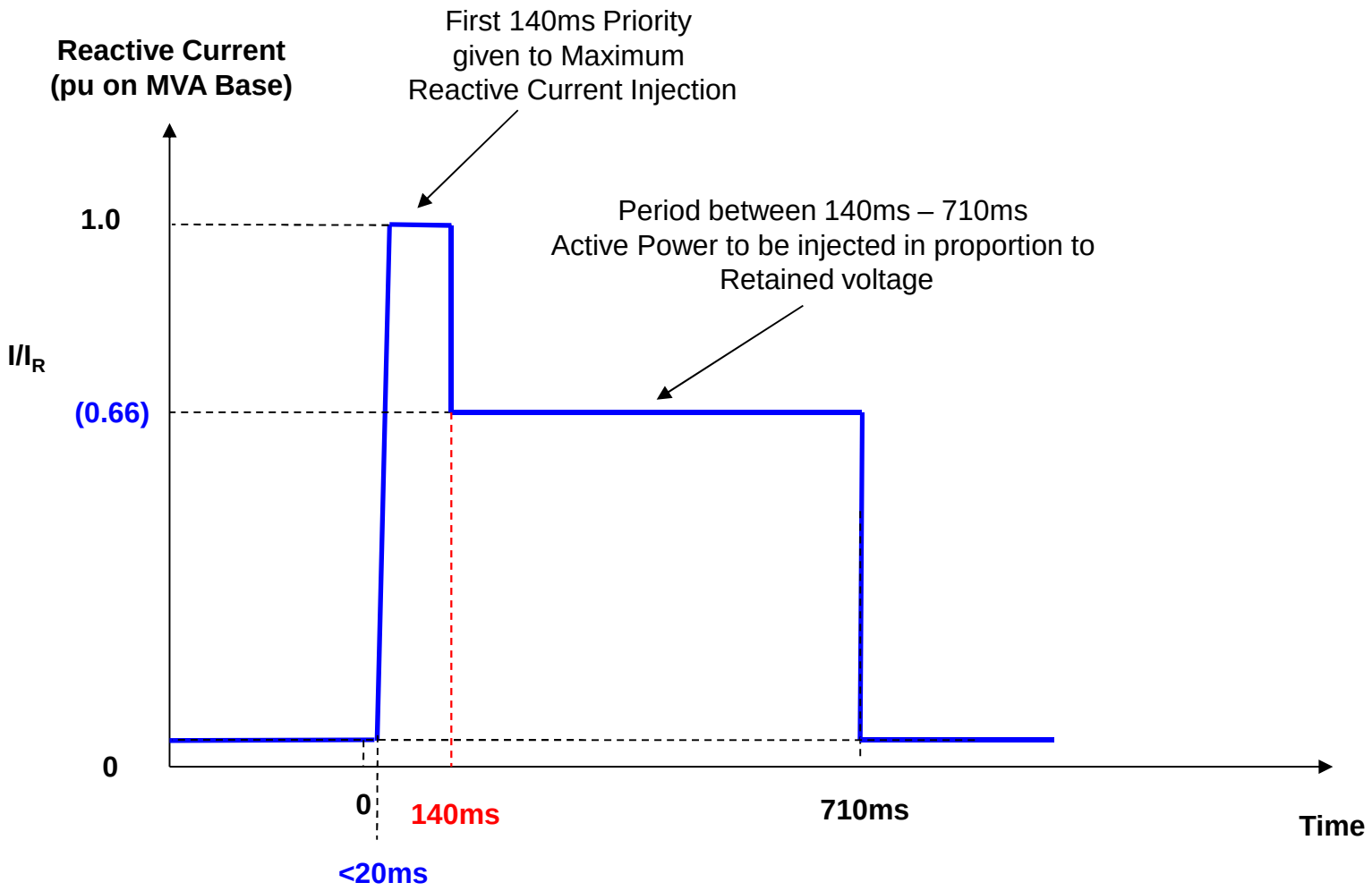


Example 3 - Voltage dip in excess of 140ms - 50% Retained Voltage



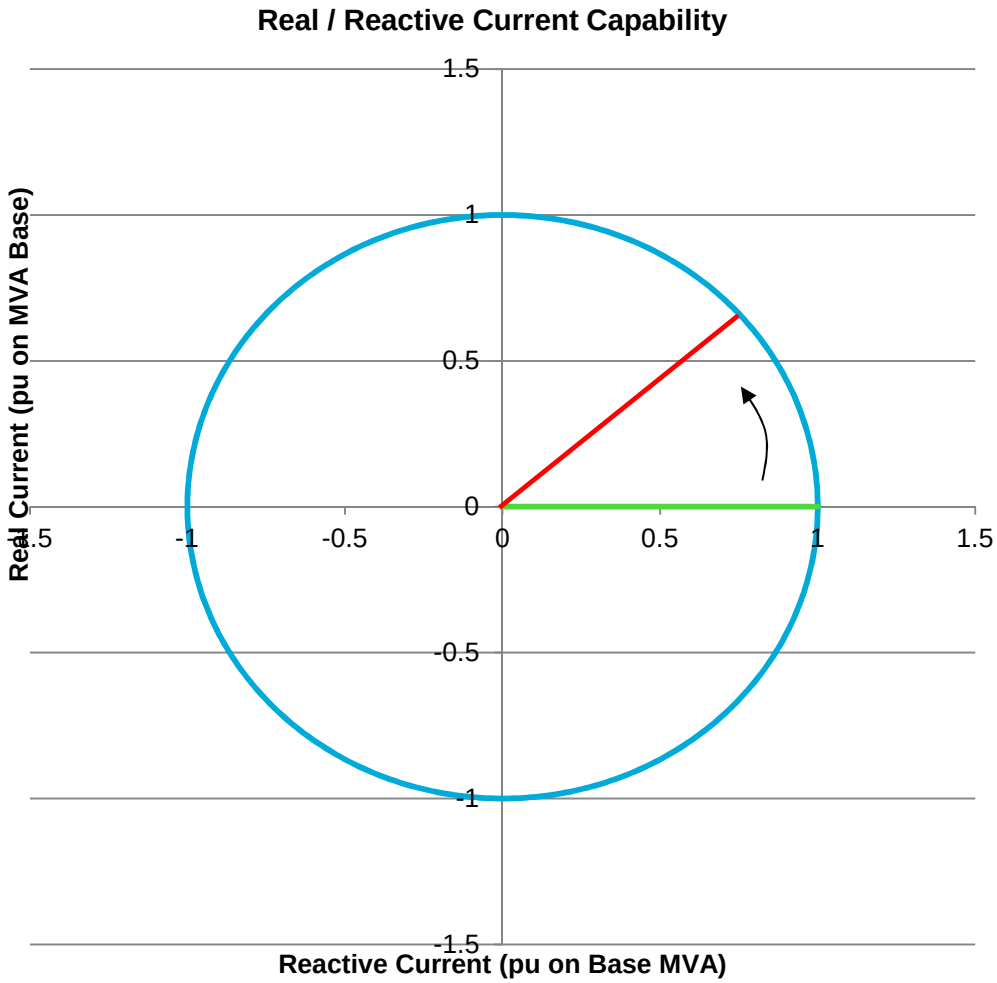
50% retained voltage, 710ms duration

Example 3 – Required Reactive Current injection for a 50% retained voltage for 710ms



50% retained voltage, 710ms duration

Example 3 – Circle Diagram - 50% Retained Voltage



Related Issues

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- The requirements of ECC.6.3.15.9 (faults in excess of 140ms) continue to apply to Type C and Type D Power Park Modules
- During the period of the fault, reactive current injection is the primary driver to support system voltage – a fundamental prerequisite for fault ride through.
- Restoration of Active Power following fault clearance is the fundamental requirement to avoid system frequency collapse
- For voltage depressions in excess of 140ms – eg a widespread voltage depression caused by say a stuck breaker which would be cleared in backup operating times, the requirement (as currently codified in the Grid Code – both the CC's and ECC's) is to provide Active Power at least in proportion to the retained voltage at the Connection Point and generate maximum reactive current without exceeding the transient rating of the Power Park Module or OTSDUW Plant and Apparatus
- These requirements are not included in G99 as they are a continuation of the existing Grid Code and fall outside the requirements of RfG.

Summary

- For faults cleared in up to 140ms, priority to be given to reactive current injection without exceeding the transient rating of the Power Park Module or HVDC Equipment.
- For faults in excess of 140ms, the reactive current injection should be above the shaded boundary shown in Figures ECC.16.3.16(a) and ECC.16.3.16(b), as soon as the voltage falls below the minimum levels in ECC.6.3.16
- For faults in excess of 140ms, Type C and Type D Power Park Modules and OTSDUW Plant and Apparatus are required to provide Active Power at least in proportion to the retained voltage at the Connection Point and generate maximum reactive current without exceeding the transient rating of the Power Park Module or OTSDUW Plant and Apparatus

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Legal Text – Workgroup Discussions

- Text circulated to Workgroup members for comment on 27 June
- ECC.6.3.16 updated in draft form to provide clarification and address the defect raised
- Stakeholders requested to review draft text and establish if it provides the clarity sought
- Further issues / areas for improved text?
- Process for proceeding to the next phase

Impact and Assessment

Impact of the modification on the Relevant Objectives:	
Relevant Objective	**Identified impact**
To permit the development, maintenance and operation of an efficient, coordinated and economical system for the transmission of electricity	Positive
To facilitate competition in the generation and supply of electricity (and without limiting the foregoing, to facilitate the national electricity transmission system being made available to persons authorised to supply or generate electricity on terms which neither prevent nor restrict competition in the supply or generation of electricity)	Positive
Subject to sub-paragraphs (i) and (ii), to promote the security and efficiency of the electricity generation, transmission and distribution systems in the national electricity transmission system operator area taken as a whole	Neutral
To efficiently discharge the obligations imposed upon the licensee by this license and to comply with the Electricity Regulation and any relevant legally binding decisions of the European Commission and/or the Agency; and	Positive
To promote efficiency in the implementation and administration of the Grid Code arrangements	Neutral
Distribution Code Relevant Objectives	
Permit the development, maintenance, and operation of an efficient, coordinated and economical System for the distribution of electricity.	Neutral
Facilitate competition in the generation and supply of electricity.	Neutral
Efficiently discharge the obligations imposed upon DNOs by the Distribution Licence and comply with the Regulation (where Regulation has the meaning defined in the Distribution Licence) and any relevant legally binding decision of the European Commission and/or Agency for the Co-operation of Energy Regulators.	Positive
Promote efficiency in the implementation and administration of the Distribution Code	Neutral

Implementation

- This modification needs to be progress without delay so that manufacturers gearing up for producing compliant equipment by the May 2019 deadline are in no doubt about the necessary performance requirements.

Next Steps

- Workgroup Report to be submitted to Grid Code Review Panel in Sept
- Decide on Workgroup Consultation
- Workgroup 2 to finalise Workgroup Report and to convene on August Workgroup Day (1 August)