Fast Fault Current Injection

Antony Johnson
National Grid – Technical Policy

Current Position

- At the last joint HVDC Workgroup meeting, it was proposed to see if it was possible to retain the existing GB wording within the framework of the EU Code.
- It is our understanding (legal view) that partial adoption of Fast Fault Current injection to the extent defined in the current GB code is not acceptable. As such full adoption is considered in detail in the following slides.

GB Grid Code Requirements

- Within the GB Grid Code requirements for reactive current injection are loosely covered in CC.6.3.15.
  - Requirement to inject maximum reactive current during the period of the fault without exceeding the transient rating of the Power Park Module, Generating Unit or OTSDUW apparatus
  - Applies both to balanced and un-balanced faults up to 140ms in duration.
  - HVDC connections are separately specified in Bilateral Agreements
  - Active Power to be restored within 0.5 seconds of restoration of the voltage at the Grid Entry Point to the minimum levels specified in CC.6.1.4
  - Active Power oscillations will be acceptable provided that
    - The total active energy delivered during the period of the oscillations is at least that which would be delivered if the Active Power was constant
    - The Oscillations are adequately damped

Existing Grid Code obligation for fast fault current injection

- GB Grid Code provides an existing obligation under CC6.3.15.1. (a) ii) that:-
  - " each Generating Unit or Power Park Module or OTSDUW Plant and Aparatus shall generate maximum reactive current without exceeding the transient rating limit.."
  - DC Converters shall be designed to meet the requirements of the Bilateral Agreement.
- As such we do not start with a clean page on Fast Fault Current injection, we need to consider how best to potentially adapt it into the framework provided for under the EU code, and the extent to which such adaptation is required.

RfG Requirements for Fast Fault Current Injection

nationalgrid

- Applies for Type B and above Power Park Modules
- Defined in RfG Article 20(2)(b) and Article 20(3)
- For Type B, steady state reactive range and associated performance chart is not specified under RfG. As such it is not clear how the scales of reactive injection available are determined.
- The use of fixed power factor is not precluded by the above, however it should not inhibit reactive current injection during fault conditions.

RfG Requirements for Fast Fault Current Injection (1) – Article 20(2)(b)

nationalgrid

- Article 20(2)(b) – The relevant System Operator in coordination with the relevant TSO *shall have the right to specify* that a power park module be capable of providing fast fault current injection at the connection point in the case of symmetrical (3-phase) faults under the following conditions:
  - (i) the power park module shall be capable of activating the supply of fast fault current either by:
    - Ensuring the supply of the fast fault current at the connection point: or
    - Measuring voltage deviations at the terminals of the individual units of the power park module and providing a fast fault current at the terminals of these units.

RfG Requirements for Fast Fault Current Injection (2) – Article 20(2)(b)

- (ii) the relevant system operator in co-ordination with the relevant TSO shall specify
  - How and when a voltage deviation is to be determined as well as the end of the voltage deviation
  - The characteristics of the fast fault current, including the time domain for measuring the voltage deviation and fast fault current, for which current and voltage may be measured differently from the method specified in Article 2;
  - The timing and accuracy of the fast fault current, which may include several stages during a fault and after its clearance;

(c) With regard to the supply of fast fault current in case of asymmetrical (1-phase or 2-phase faults, the relevant system operator in co-ordination with the relevant TSO shall have the right to specify a requirement for asymmetrical current injection

(note under CC. 6.3.15.1.(a) (i) and (ii) Users should supply fast fault current in respect of balanced and unbalanced fault conditions)

Fast Fault Current Injection Definition – RfG Article 2

- ‘fast fault current’ 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;

RfG Requirements for Fast Fault Current Injection (3) – Article 20(3)

nationalgrid

- Type B power park modules shall fulfil the following additional requirements in relation to robustness.:
- (a) the relevant TSO shall specify the post fault active power recovery that the power park module is capable of providing and shall specify:
  - (i) when the post fault active power begins, based on a voltage criterion
  - (ii) a maximum allowed time for active power recovery; and
  - (iii) a magnitude and accuracy for active power recovery;
- (b) the specifications shall be in accordance with the following principles
  - (i) interdependency between fast fault current requirements according to points (b) and (c) and paragraph (2) and active power recovery;
  - (ii) dependence between active power recovery times and duration of voltage deviations
  - (iii) a specified limit of the maximum allowed time for active power recovery
  - Adequacy between the level of voltage recovery and the minimum magnitude for active power recovery and
  - Adequate damping of active power oscillations

RfG Requirements
Article 21(3)(e) – Type C PPM's

nationalgrid

- With regard to prioritising active or reactive power contribution, the relevant TSO shall specify 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, this provision has to be established no later than 150ms from the fault inception.
- In existing GB code, full active power should be restored within 500ms of fault clearance for Type A faults.

Proposals for Reactive Current injection under balanced fault conditions

nationalgrid

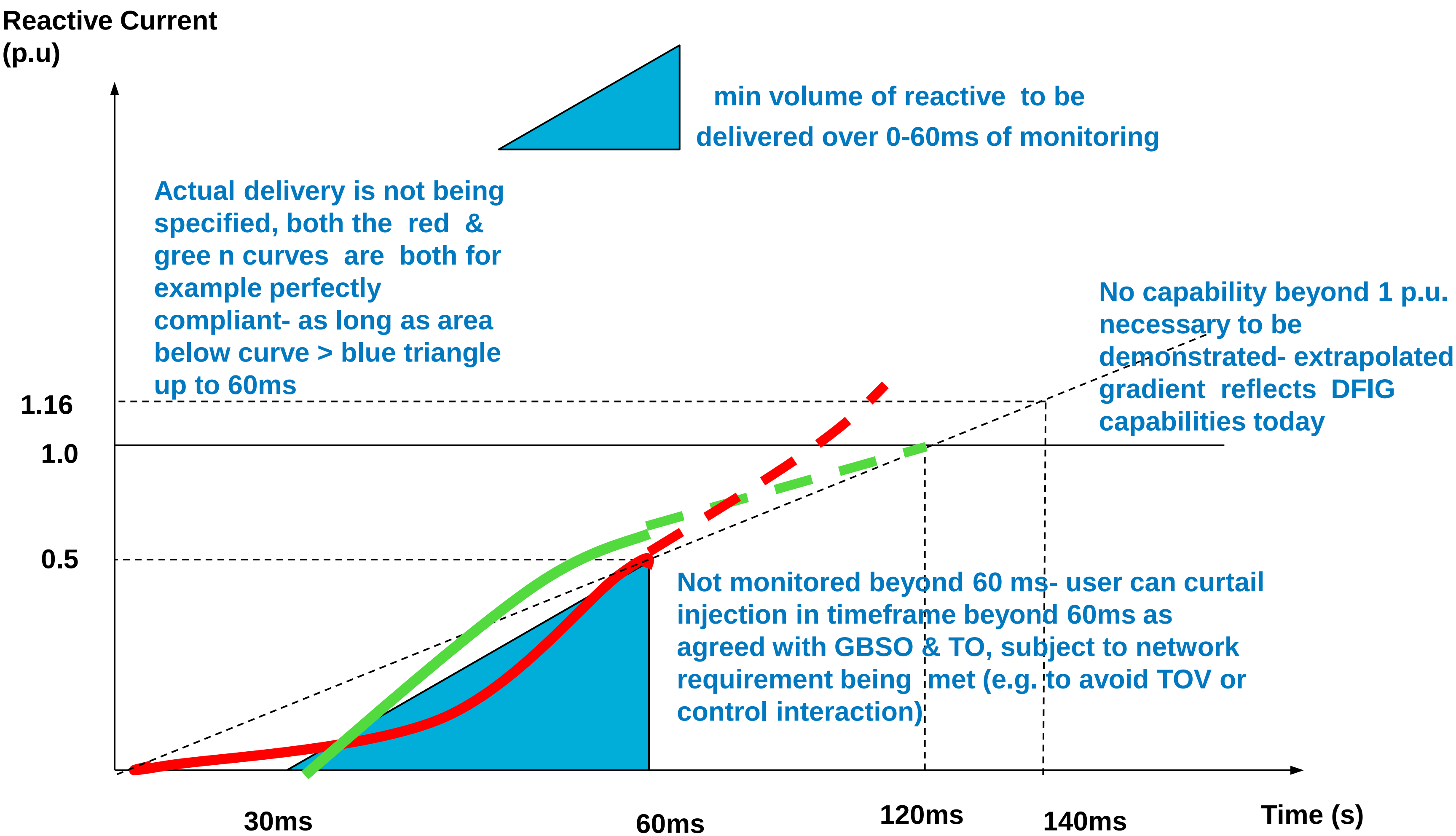
- Applies at the Connection Point
- Provide equivalent OTSDUW, PPM and HVDC specification.
- Voltage deviation is any event where the connection point balanced RMS voltage falls below 0.9p.u, consistent with the existing GB Grid code requirements of definition of RMS voltage with reference to voltage fluctuation within CC. 6.1.7:-
  - Measured over one cycle, refreshed every half cycle (IEC 61000-4-30)
  - Steady state reference voltage is defined as per CC. 6.1.7. (a) (iii)
- For a solid three phase short circuit fault a PPM should inject maximum reactive current without exceeding any transient rating and be no less than the requirement below.
  - The total transient reactive current injection capability should be demonstrated to at least be no less than 1p.u. of the Rated MW equivalent active current during steady state conditions.
  - Reactive current injection to be observable within 30ms of the fault
  - Over the period 30ms-60ms the total time averaged reactive current injection should be at least 50% of the maximum transient injection across the period 0-60ms
  - The delivery of fast fault current beyond 60ms will depend on particular network recovery dynamics and may be subject bilateral specification as required to support stable recovery
- Upon restoration of the voltage to nominal levels (> 90%), active power should be restored to 90% of the pre-fault value within 0.5 seconds of fault clearance provided voltage does not exceed 1.05p.u.
- Reactive current injection is only required during the period of the fault and not following fault clearance. Following fault clearance reactive current should be used to support regulation of the voltage to within 0.9-1.05p.u Voltage limits as defined in CC6.1.4. at 400kV.
- The Power Generating Facility owner should submit a time trace of reactive current injection before during and after the fault.

High level proposals for Reactive Current injection under three phase fault conditions – Summary

nationalgrid

Requirement	Specification
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 0.9p.u
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 Article 2	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 timing and accuracy of the fast fault current, which may include several stages during a fault and after its clearance	Power Park Module Facility Owner 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 30-60ms?
When post fault active power recovery begins based on a voltage criterion	Active Power Recovery to commence on fault clearance (ie voltage above 0.9p.u, but less than 1.05p,u)
Maximum allowed time for active power recovery	Active Power to be restored within 0.5 seconds of fault clearance (ie voltage above 0.9p.u)
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. For the avoidance of doubt a balanced Onshore Transmission System Supergrid Voltage meets the requirements of CC.6.1.5(b) and CC.6.1.6.

Reactive Current Injection



Reactive Current Injection

- Further discussion required
- Request from stakeholders and manufacturers to provide examples of reactive current injection performance requirements.
  - Power Park Modules
    - Fixed Speed – No issue expected
    - Doubly fed induction generators
    - Full Converter fed machines
  - HVDC Converters (VSC and CSC)
- Additional research undertaken – University of Strathclyde
  - Implications on Protection

Unbalanced Faults

- Requires further discussion
- Initial starting point would be to adopt the same requirements as currently specified under the GB Code.

Discussion