GRID CODE
Modification Proposal

Active power recovery after fault ride through events in respect of Large Power Park Units

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1 Introduction

This paper is intended to be presented to the grid code review panel (GCRP) to discuss a possible modification of the performance requirements of the FRT within the grid code.

In particular the time of active power recovery after faults.

2 Background

The capability of active power recovery from power park modules/ units after low voltage events (fault ride through) depends on several factors. The following factors have been identified

- method of connection of the generator to the grid (direct connected generator or converter connected)
- drive-train concept (long shaft or integrated)
- the operational state (partial load, full load, any change)
- depth and length of the voltage depression
- drive-train inertia and stiffness

The current description within the grid code CC.6.3.15 implies a direct relationship between the duration of the fault and the time the unit takes to recover the active power after the event i.e. CC.6.3.15.1 calls for a total fault clearance time of up to 140 ms to recover active power within 0.5 seconds of restoration of the voltage and for a total fault clearance greater than 140 ms to recover active power within 1 seconds of restoration of the voltage.
Current information about power park units using long-shafts technology suggest a reverse relationship i.e. units exposed to longer less severe fault are capable to recover their active power quicker than units exposed to short severe faults (see example measurements in figure 1 and 3). It is expected that a similar relationship is existing for all PPU technology using long shafts, where blade mass, gearbox and generator are able to oscillate. However, there is not sufficient data available at this point in time.
As the up-scaling of power park units using technology with long shafts beyond 3MW size continues, the PPU's will not be able to fulfil current grid code requirements.

2.1 Power park unit response

A rapid voltage depression as assumed for fault ride through events causes high drive train torque and speed oscillation for PPU's. In order to ensure a stable further operation and to ride through the fault, there is a need to reduce this mechanical impact on the drive train, caused by a fast change of generator torque due to the voltage change. Torque, power and speed are dependant in the following way.

$$torque = \frac{power}{speed}$$

The damping of the oscillations and the torque is therewith directly affecting the performance of the active power of the PPU. Thereby there is a trade-off between reducing the loads on the drive train (torque) and damping of the oscillations (speed change).
The oscillation frequency and therewith the time it takes to damp the oscillation depends on the Drive train resonance frequency. The resonance frequency is lower with larger inertia within the growing PPU size. The nominal torque, which is required to recover the active power, is first available after a completed period of the oscillation.
The minimum possible time it takes to recover active power after a short fault ride through can be approximated within the following formula.

$$T_{rise} = T_{DT} - T_{drop}$$

were

$$T_{DT} = \frac{1}{f_{DT}}$$

T_{DT} - time of one period of the drive train oscillation

f_{DT} - drive train resonance frequency

T_{drop} - time duration of fault

T_{rise} - recover/ rise time of active power post fault

Therewith it can be shown, that the recovery time for active power after the fault is shorter for longer fault time durations and longer for low resonance frequencies. Therewith it is a technology inherent that the active power restoration can not be significantly increased.

There are two options to improve shorten the recovery time.

1) increase the general drive train speed
2) allow higher torque oscillation

Both options will have a significant impact on the costs of PPU's e.g. for a PPU with long shaft technology a 0.1s quicker recovery shows about 20% higher mechanical loading on the drive train.

2.1.1 Example measurements

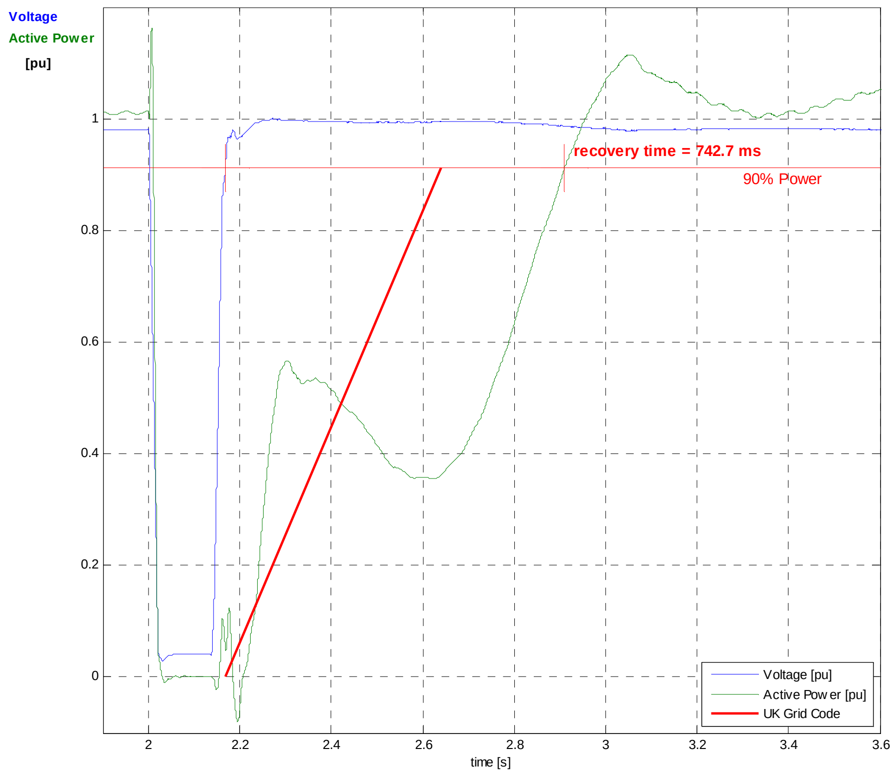

Figure 1: Measurement of a Voltage Drop to 4%, 140ms, full load

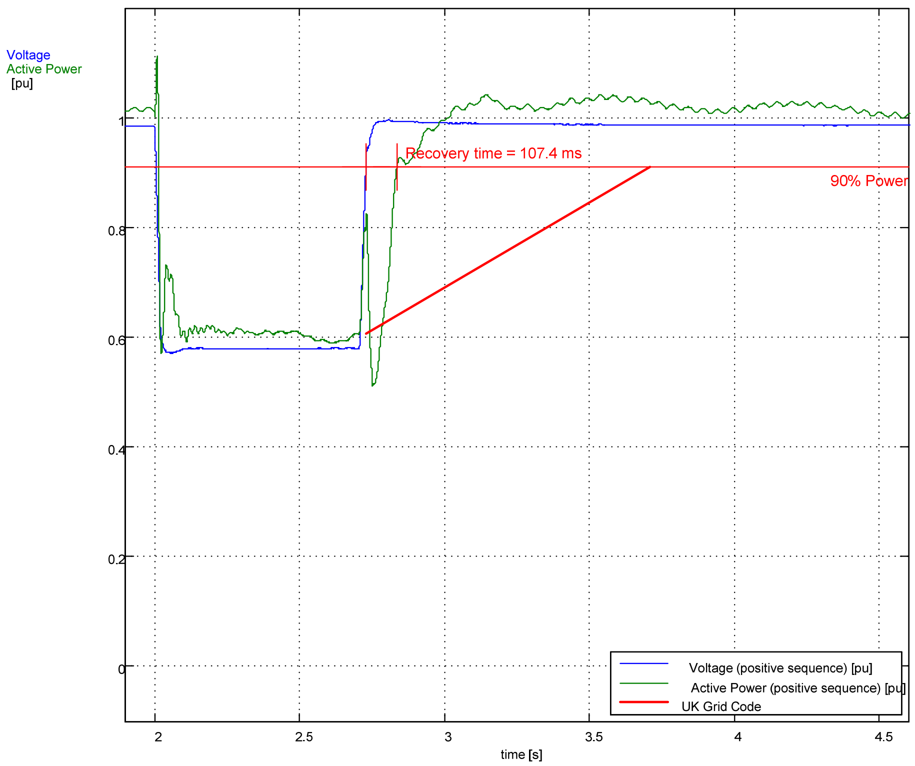

Figure 2: Voltage Drop to 48%, 710ms, full load

3 Affected grid code section

Reference:
National Grid Electricity Transmission plc: „The Grid Code, Issue 4 Revision 2, 22nd March 2010"
The following effected section has been unchanged since 24th June 2009.

"***CC.6.3.15.1*** *Fault Ride through applicable to Generating Units, Power Park Modules and DC Converters*
(a) ***Short circuit faults*** *on the* ***Onshore*** *Transmission System (which may include an Interface Point) at Supergrid Voltage* ***up to 140ms*** *in duration.*
[…]
(ii) Each Generating Unit or Power Park Module shall be designed such that upon both clearance of the fault on the Onshore Transmission System as detailed in CC.6.3.15.1 (a) (i) and within ***0.5 seconds*** *of the restoration of the voltage at the Onshore Grid Entry Point (****for Onshore Generating Units*** *and Onshore Power Park Modules) or Interface Point (****for Offshore Generating Units*** *and Offshore Power Park Modules) to the minimum levels specified in CC.6.1.4 (or within* ***0.5 seconds*** *of restoration of the voltage at the User System Entry Point to 90% of nominal or greater if Embedded), Active Power output shall be restored to at least 90% of the level available immediately before the fault. Once the Active Power output has been restored to the required level, Active Power oscillations shall be acceptable provided that:*
- the total Active Energy delivered during the period of the oscillations is at least that which would have been delivered if the Active Power was constant
- the oscillations are adequately damped"[…]
(b) Supergrid Voltage dips on the Onshore Transmission System ***greater than 140ms*** *in duration In addition to the requirements of CC.6.3.15.1 (a) each Generating Unit or Power Park Module and / or any constituent Power Park Unit, each with a Completion Date on or after the 1 April 2005 shall: […]*
(iii) restore Active Power output, following Supergrid Voltage dips on the Onshore Transmission System as described in Figure 5, ***within 1 second*** *of restoration of the voltage at the:-*
Onshore Grid Entry Point for directly connected ***Onshore Generating Units*** *and Onshore Power Park Modules or,*
Interface Point ***for Offshore Generating Units*** *and Offshore Power Park Modules or, […]*

"***CC.6.3.15.2*** *Fault Ride Through applicable to* ***Offshore*** *Generating Units at a Large Power Station, Offshore Power Park Modules at a Large Power Station and Offshore DC Converters at a Large Power Station who choose to meet the fault ride through requirements at the LV side of the Offshore Platform*
[…]
(b) […] (iii) within ***1 second*** *of the restoration of the voltage at the LV Side of the Offshore Platform (to the minimum levels specified in CC.6.1.4) restore Active Power to at least 90% of the Offshore Generating Unit's or Offshore Power Park Module's immediate pre-disturbed value, unless there has been a reduction in the Intermittent Power Source in the time range in Figure 7 that restricts the Active Power output below this level. Once the Active Power output has been restored to the required level, Active Power oscillations shall be acceptable provided that:*

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

4 Application for Grid Code Change

REpower applies for a modification of the Grid Code section "CC.6.3.15.1 (a) (ii)":
The required time of 0.5 seconds for active power restoration after short circuit faults up to 140ms should be changed to 1 second, as is already required after short circuit faults greater than 140ms.

Proposed Grid Code Change:
"*CC.6.3.15.1 Fault Ride through applicable to Generating Units, Power Park Modules and DC Converters*
(a) Short circuit faults on the Onshore Transmission System (which may include an Interface Point) at Supergrid Voltage up to 140ms in duration.
[…]
(ii) Each Generating Unit or Power Park Module shall be designed such that upon both clearance of the fault on the Onshore Transmission System as detailed in CC.6.3.15.1 (a) (i) and within ***1 second*** *of the restoration of the voltage at the Onshore Grid Entry Point (for Onshore Generating Units and Onshore Power Park Modules) or Interface Point (for Offshore Generating Units and Offshore Power Park Modules) to the minimum levels specified in CC.6.1.4 (or within* ***1 second*** *of restoration of the voltage at the User System Entry Point to 90% of nominal or greater if Embedded), Active Power output shall be restored to at least 90% of the level available immediately before the fault. Once the Active Power output has been restored to the required level, Active Power oscillations shall be acceptable provided that:*
- the total Active Energy delivered during the period of the oscillations is at least that which would have been delivered if the Active Power was constant
- the oscillations are adequately damped"[…]

5 Grid code modification discussion

The modification of the grid code in unifying the required time for active power recovery to 1 second for all FRT would be a simplification of the requirement, which consequently reduces workload on evaluation of grid code compliance.

Insisting on 0.5 second recovery leads due to the inherent effect within the technology to discrimination of PPU's with long shaft technology and to become grid code non compliant through upscaling. This consequently might have an impact on the availability of large wind turbines to fulfil UK's renewable energy targets. See Figure 3 for an overview of the current existing PPU's dependant on their grid connection. It is to note, that most current wind turbines are using long shaft technology.

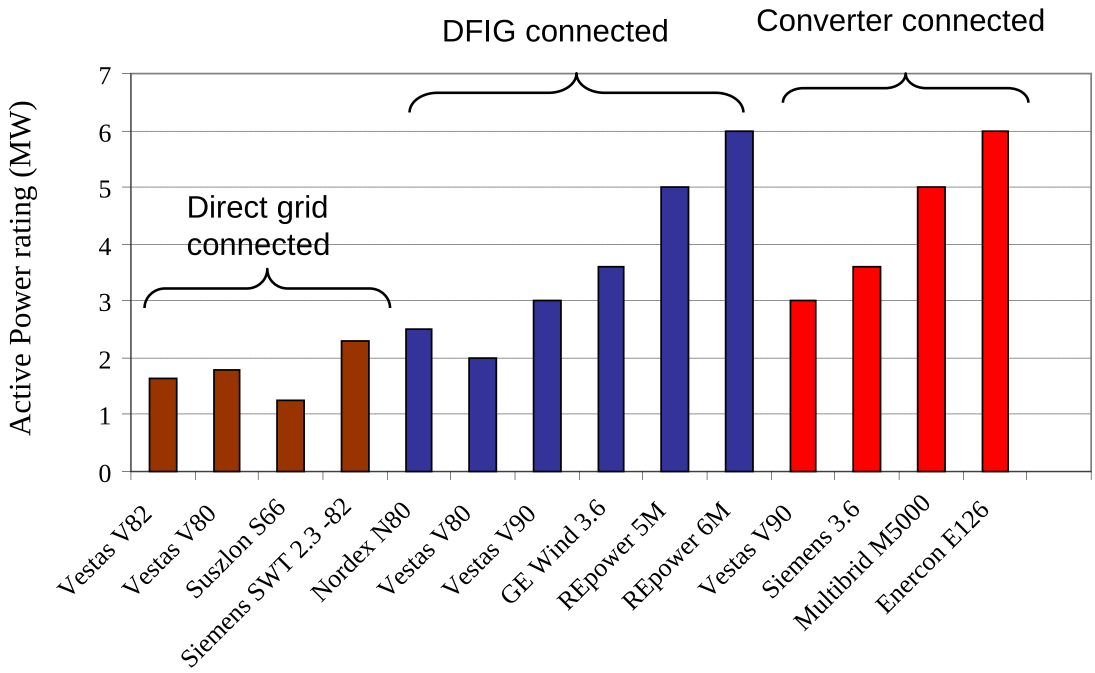

Figure 3 Current available wind turbine technology

The effect on the wider security and quality of supply benefits would need to be investigated.
Thereby it is to note, that the frequency response is currently under review due to the change of single loss of generation from currently 1350MW to 1800MW due to the new installation of a nuclear plant.
This requires a review of the response to faults and the review of the required active power recovery after faults.
Most PPU's are not directly connected to the transmission network and would therefore not be exposed to the actual fault as described within the grid code. Consequently the effect of this change is considered to be not of major significance and poses an unnecessary requirement onto PPU's performance.

The modification would also allow National Grid to better meet its duties under Clause 1b(ii) and Clause 11 of the standard conditions of Electricity Transmission Licence as shown below:

Condition is c14 – Grid Code
http://epr.ofgem.gov.uk/document_fetch.php?documentid=15184

Clause 11 of the Condition requires;

> "In preparing, implementing and complying with the Grid Code (including in respect of the scheduling of maintenance of the national electricity transmission system), *the licensee shall not unduly discriminate against or unduly prefer any person or class or classes of person in favour of or as against any person or class or classes of persons.*"

Clause 1 b(ii), in preparing and implementing the Grid Code, National Grid is required;

"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) ;