Hybrid STATCOM / SVC Workgroup 15th May 2014

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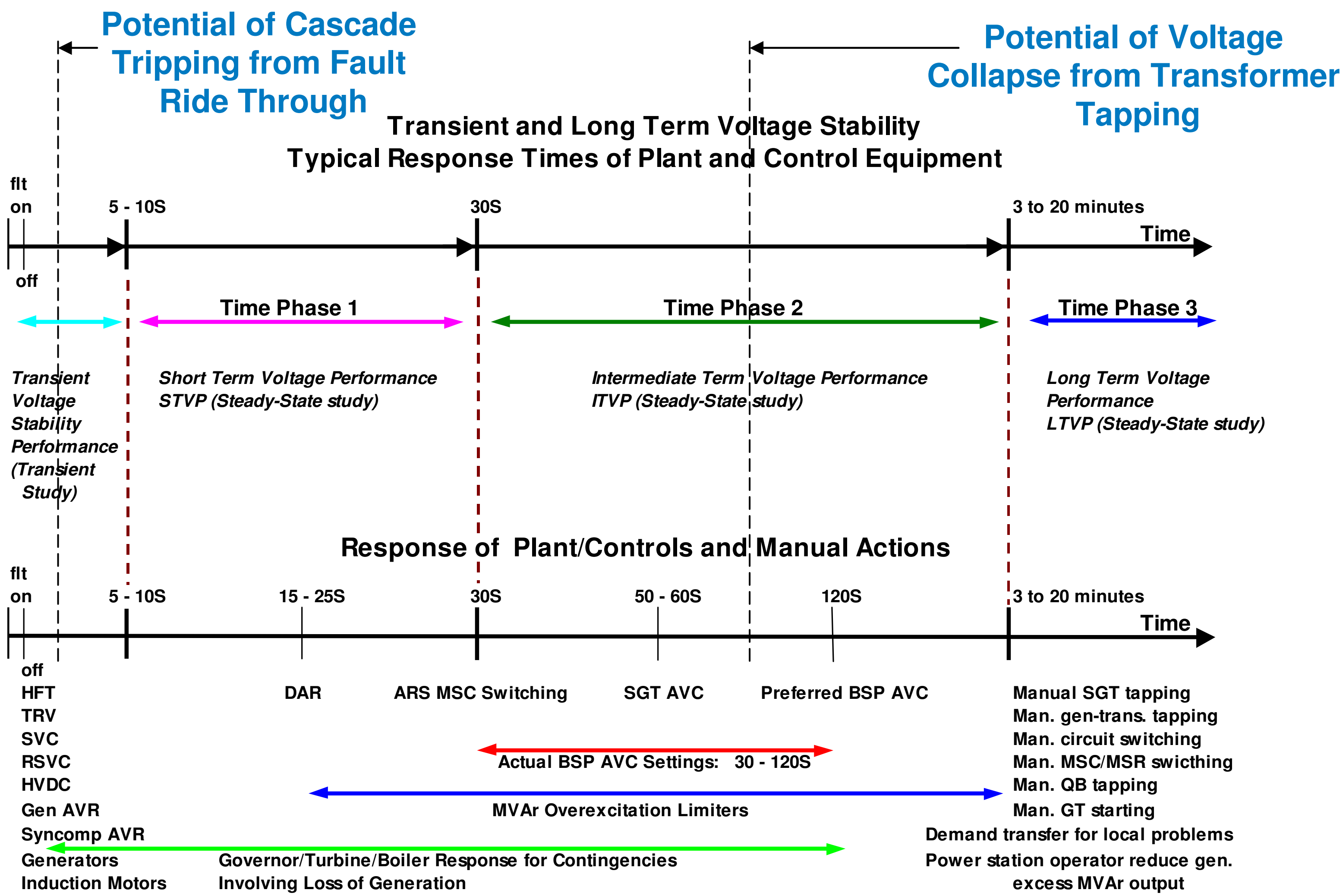
Overview

- High Level Continuous Voltage Control & Reactive Capability Requirement
- History:
  - GB Grid Code
  - History & Current Position
  - European RfG Requirements
- DAR Operation & Timing Diagrams
- Fault Ride Through
- Improvement – What's possible and at what cost?
- Summary
- Discussion

High Level Requirement for Continuous Voltage Control & Reactive Capability

- Required to:-
  - Ensure system voltage is maintained within SQSS limits any dips below 0.85pu last <2.5secs to prevent cascade tripping on FRT
  - Ensure an initial reactive power response within 1 second as currently defined in the GB Grid Code
  - Ensure delivery of available reactive reserves during critical events
  - Ensure repeatable response within DAR and operator time scales
  - Ensure consistency with RfG
  - Ensure a response provided in the event of interactions with similar equipments in adjacent Power Parks
  - Ensure repeatable response such that contingency and defence studies produce reliable results

Transient & Long-Term Stability: Time Phases



GB Grid Code

- **CC.6.3.6 (b)** Each (i) **Onshore Generating Unit**; or (ii) **Onshore DC Converter** (with a **Completion Date** on or after 1 April 2005 excluding current source technologies); or (iii) **Onshore Power Park Module** in England and Wales with a **Completion Date** on or after 1 January 2006; or (iv) **Onshore Power Park Module** in Scotland irrespective of **Completion Date**; or (v) **Offshore Generating Unit** at a **Large Power Station**, **Offshore DC Converter** at a **Large Power Station** or **Offshore Power Park Module** at a **Large Power Station** which provides a reactive range beyond the minimum requirements specified in CC.6.3.2(e) (iii), must be capable of contributing to voltage control by continuous changes to the **Reactive Power** supplied to the **National Electricity Transmission System** or the **User System** in which it is **Embedded**.
- **APPENDIX 7** - PERFORMANCE REQUIREMENTS FOR **CONTINUOUSLY ACTING AUTOMATIC VOLTAGE CONTROL SYSTEMS**
- **CC.A.7.2.2.1** The Onshore Non-Synchronous Generating Unit, Onshore DC Converter, Onshore Power Park Module or OTSDUW Plant and Apparatus **shall provide continuous steady state control of the voltage** at the Onshore Grid Entry Point (or Onshore User System Entry Point if Embedded) (or the Interface Point in the case of OTSDUW Plant and Apparatus) with a Set point Voltage and Slope characteristic as illustrated in Figure CC.A.7.2.2a…
- **CC.A.7.2.2.5** Should the operating point of the Onshore Non-Synchronous Generating Unit, Onshore DC Converter, OTSDUW Plant and Apparatus or Onshore Power Park Module deviate so that it is no longer a point on the operating characteristic (figure CC.A.7.2.2a) defined by the target Set point Voltage and Slope, **the continuously acting automatic voltage control system shall act progressively to return the value to a point on the required characteristic within 5 seconds**.
- **CC.A.7.2.3.1** **For an on-load step change** in Onshore Grid Entry Point or Onshore User System Entry Point voltage, or in the case of OTSDUW Plant and Apparatus an on-load step change in Transmission Interface Point voltage, the continuously acting automatic control system shall respond according to the following minimum criteria:
  - (i) **the Reactive Power output response** of the Onshore Non-Synchronous Generating Unit, Onshore DC Converter, OTSDUW Plant and Apparatus or Onshore Power Park Module **shall commence within 0.2 seconds of the application of the step. It shall progress linearly although variations from a linear characteristic shall be acceptable provided that the MVAr seconds delivered at any time up to 1 second are at least those that would result from the response shown in figure CC.A.7.2.3.1a.**
  - (ii) the response shall be such that, for a sufficiently large step, **90% of the full reactive capability** of the Onshore Non-Synchronous Generating Unit, Onshore DC Converter, OTSDUW Plant and Apparatus or Onshore Power Park Module, as required by CC.6.3.2 (or, if appropriate, CC.A.7.2.2.6 or CC.A.7.2.2.7), **will be produced within 1 second**.
  - (iii) **the magnitude of the Reactive Power output response produced within 1 second shall vary linearly in proportion to the magnitude of the step change**.
  - (iv) **the settling time shall be no greater than 2 seconds** from the application of the step change in voltage and the peak to peak magnitude of **any oscillations shall be less than 5% of the change in steady state** Reactive Power within this time.
  - (v) following the transient response, the conditions of CC.A.7.2.2 apply.

History and Current Position

- Compliance testing identified National Grid’s interpretation of “Continuously Acting Voltage Control” was not being met. Testers sometimes required to wait several minutes for repeated step tests.
- Grid Code panel paper recommended in the interim:
  - Hybrid SVC / STATCOM’s that have a performance such that switch recharge time (close-open-close) less than 15 seconds and capacitor discharge time of 2 seconds will be accepted.
- Grid Code Workshop and Work Group convened to look in to the matter further.

ENTSOe – RfG – Article 16 – Requirements for Type C Power Park Modules

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Article 16

3. Type C Power Park Modules shall fulfil the following requirements referring to Voltage stability:

d) With regard to Reactive Power control modes:

1) The Power Park Module shall be capable of providing Reactive Power automatically by either Voltage Control mode, Reactive Power Control mode or Power Factor Control mode.

2) For the purposes of Voltage Control mode, the Power Park Module shall be capable of contributing to Voltage control at the Connection Point by provision of Reactive Power exchange with the Network with a Setpoint Voltage covering at least 0.95 to 1.05 pu in steps no greater than 0.01 pu with a Slope with a range of at least 2 to 7 % in steps no greater than 0.5 %. The Reactive Power output shall be zero when the grid Voltage value at the Connection Point equals the Voltage Setpoint.

The Setpoint may be operated with or without a dead band selectable in a range from zero to ±5 % of nominal Network Voltage in steps no greater than 0.5 %.

Following a step change in Voltage, the Power Park Module shall be capable of achieving 90 % of the change in Reactive Power output within a time t1 to be specified by Relevant Network operator while respecting the provisions of Article 4(3) in the range of 1 - 5 seconds and settle at the value defined by the operating Slope within a time t2 to be specified by Relevant Network Operator while respecting the provisions of Article 4(3) in the range of 5 - 60 seconds, with a steady-state reactive tolerance no greater than 5 % of the maximum Reactive Power.

Current Position (as of May 2014):

New plant contracted after 2016/17 is likely to be required to comply with the above.

DAR Operation

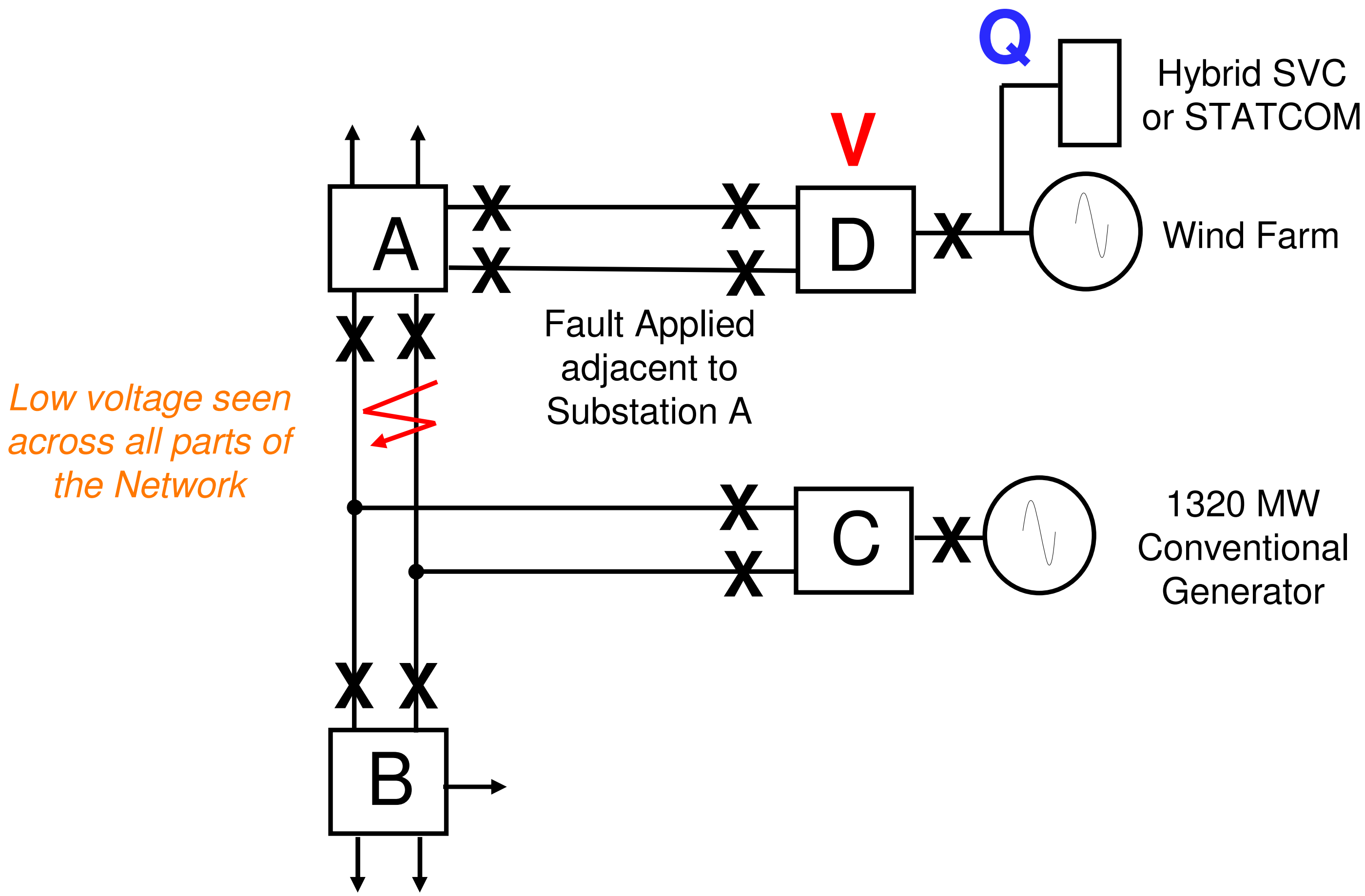
Delayed Auto Re-closure Operation:

1. DAR will automatically reclose tripped circuit breakers after the ‘Dead Time’ has expired, typically 3-20seconds. Dead time allows ionized gas to blow away or ash to fall away. NB For NG typically $\geq$15 10s (Trip Reset Times) + 5s (deadline charge).
2. On re-establishing the circuit a second timer starts, this period is known as the ‘Reclaim Time’. Faults during this period will cause a second trip which will lock out the breaker. This period typically lasts 4-20seconds. The Reclaim Time allows the insulation medium in the breaker (Oil / SF6) time to recover. For NG typically 4s.
3. If faults repeatedly occur after the Reclaim Time, operator intervention is required to lock the line out. In this scenario, further operator interventions i.e. switching operations, may require additional actions from the Hybrid SVC / STATCOM’s.

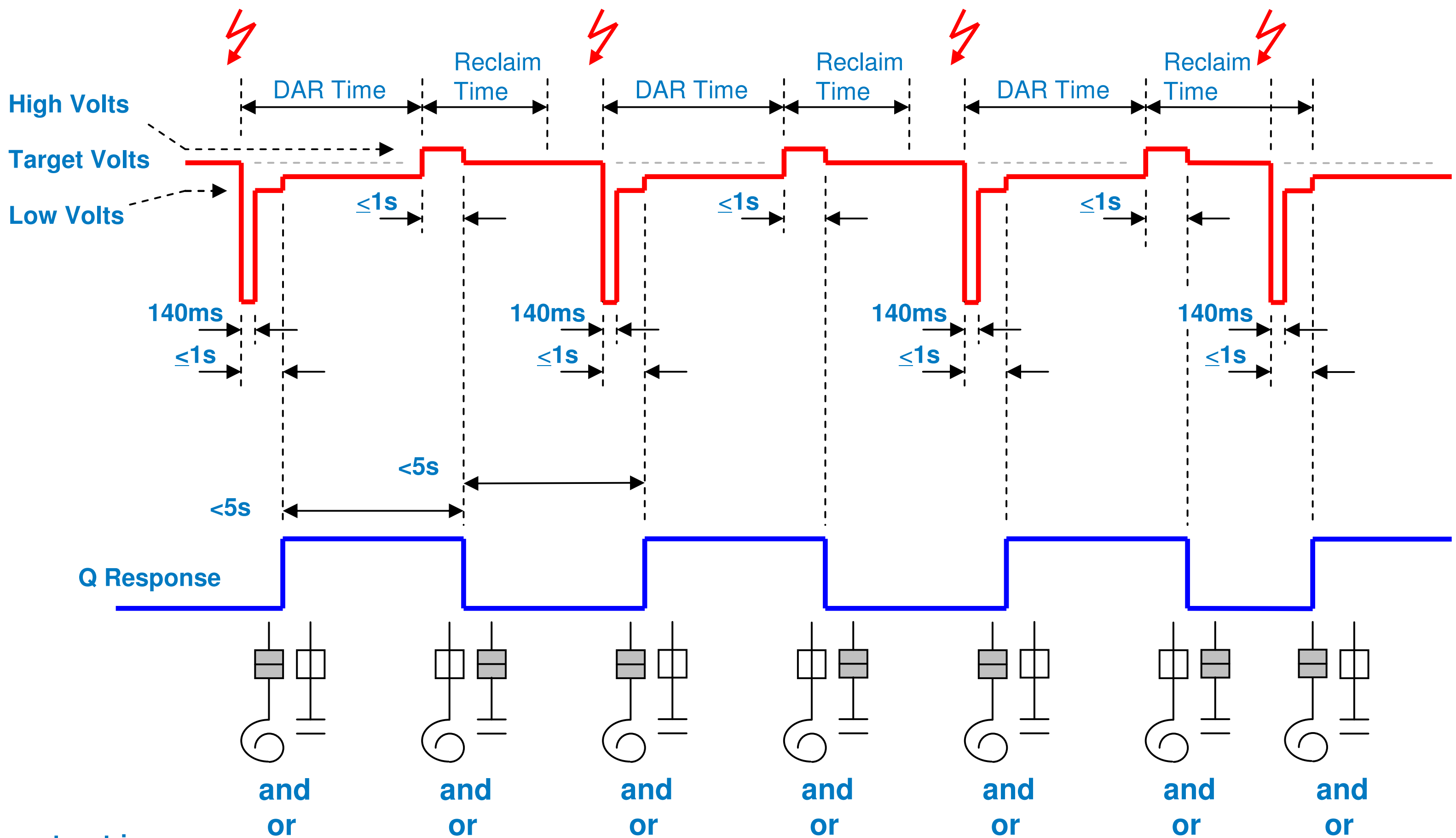
Scenarios which cause DAR operation include:

- Lightning Storm Travelling up a Line
- Debris on the line e.g. Polythene sheet
- High winds causing conductor clashing

DAR Operation



Timing Diagram
Volts at Substation D & Q Hybrid Injection vs Time



Note:
Q response to a trip can require the injection of either leading or Lagging VAr's depending on network configuration and power flows

Multiple Circuit Trip Examples

Burns Day Storm 1990 (paper records prior to 97 – only example used) – **261 trips 80 faulted circuits in 24hours**.

Wednesday/Thursday 24th/25th Dec 1997 – **33 circuits tripped in 5 Hours**.

Saturday 26th Dec 1998 – High Winds – **Approx 20 trips, including 4 DAR restorations on same line in 4mins**.

Tuesday 27th Feb 2001 – Snow & High Winds - **Multiple trips on Scot. Interconnector. 600MW generation lost**.

Tuesday 3rd Aug 2004 – Lightning – 6 Circuit Trips (5 DAR Restoration's) in 3.25Hrs

Wednesday 18th Aug 2004 – Lightning - 10 Circuit Trips in 5 Hours including **3 DAR restorations in 3mins.**

Saturday 8th Jan 2005 – Gales - **32 faults on the NG System including 6 in 18, 7 in 21, 5 in 22 and 5 in 24mins**, most of which were restored by DAR

Wednesday 31st Aug 2005 – Lightning – 11 Trips in 2hrs 21mins including **6 in 27minutes** in the same area. All recovered by DAR.

Friday 15th Jun 2006 – Lightning – 9 trips in 3 hours, several within a few minutes of each other.

Sunday 2nd Jul 2006 – Lightning - 8 trips in approx. 1.5 hours including **4 trips in 17minutes and 2 trips in 2mins**.

Wednesday 11th Oct 2006 – Lightning - 6 trips in approx. 6 hours in the Taunton area.

Thursday 18th Jan 2007 – **137 Protection operations – 51 DAR Sequences** – 3 Conductor Failures resulting in permanent loss of circuits. A further 14 trips in 4 hours including sequences of **4 trips in 40mins, 4 trips in 8mins, and 3 trips in 10mins**. Most restored by DAR.

Sunday 1st Jul 2007 – Lightning – **5 trips in a localised area in 1/2 hour 4 of which auto reclosed or where restored manually**.

Wednesday 1st Jul 2009 – Lightning – **4 trips/events over a period of 25 minutes**

Monday 15th Jun 2009 – Lightning – 8 trips and restorations (i.e. 16 in total) in 3 hours including **4 in London area in 27 minutes**.

Thursday 28th Jun 2012 – Lightning – 9 trips at various places in UK and Scotland. At about 1 hour or half hour intervals.

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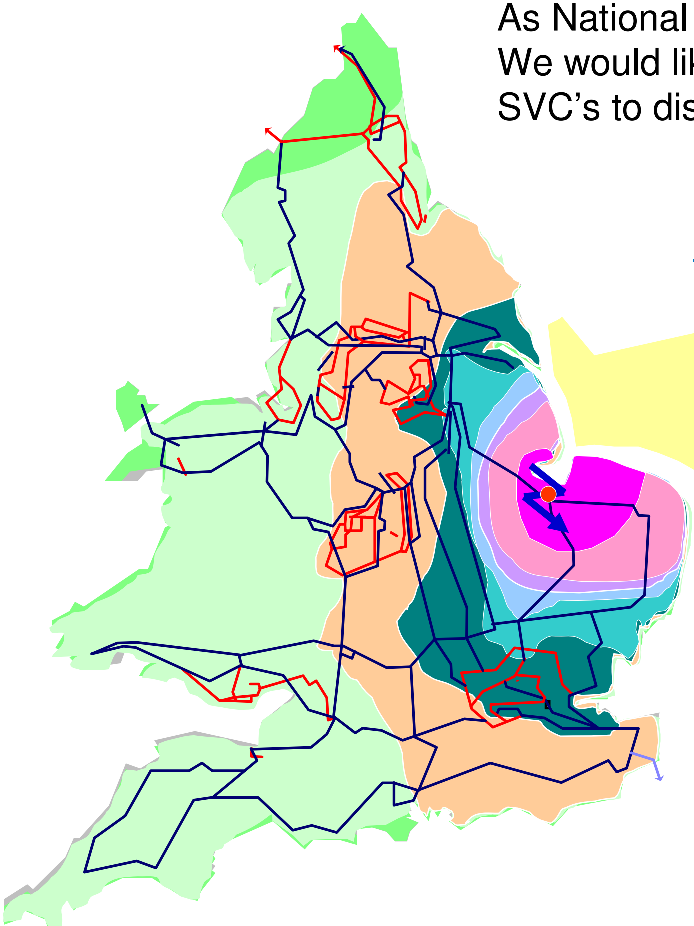
MSC Shutdown During Faults

Some Hybrid STATCOM / SVC's switch out the capacitors during a fault condition further reducing reactive support. This increases the risks from voltage depression after a fault and increases the risk of post fault voltage depression and cascade tripping.

As National Grid doesn't switch its own capacitors out during fault conditions. We would like to understand why is it necessary for some Hybrid STATCOM / SVC's to disconnect capacitors during faults?

CCA.4A.3 **SUPERGRID VOLTAGE** DIPS ON THE **ONSHORE TRANSMISSION SYSTEM** GREATER THAN 140MS IN DURATION – This allows generators to trip after 2.5seconds if the voltage falls below 85%. As a consequence failure to support the volts to within 85% could result in cascade tripping.



3 phase fault applied at Walpole 400 kV substation

Fault Location 0 %

0 - 15 % Volts

15 - 30 % Volts

30 - 40 % Volts

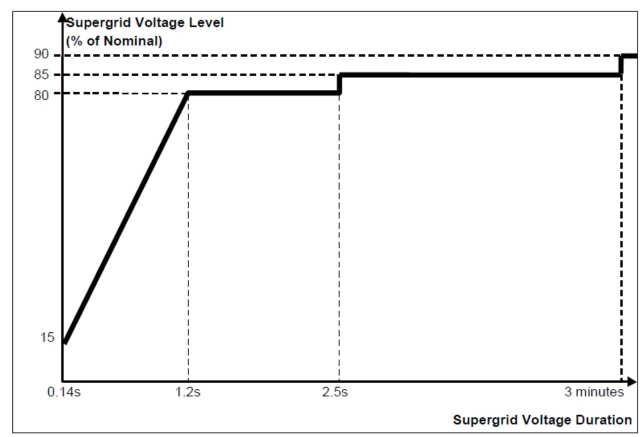
40 - 50 % Volts

50 - 60 % Volts

60 - 70 % Volts

70 - 80 % Volts

80 - 90 % Volts



Proposed Changes to GB Grid Code

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Desirable Outcome:

- Clear and well understood requirements
- Initial Response as per Current Grid Code Requirement as defined currently in CC.A.7.2.2, CC.A.7.2.3.1 and CC6.3.2
- All subsequent switching actions are visibly faster than DAR ≤5 seconds ensuring requirement CC.A.7.2.2.5 or CC.A.7.2.3.1(ii) is always met within 5 seconds and all other aspects of CC.A.7.2.2, CC.A.7.2.3.1 and CC6.3.2 are met there after.
- All Actions are Repeatable, Consistent, Predictable and Continuously Available including switching.
- [X] seconds after the last switching event performance returns to requirements defined in CC.A.7.2.2, CC.A.7.2.3.1 and CC6.3.2
- Consequences:
  - What improvement in performance can be achieved?
  - What is the impact on cost?
  - What time frames can any solution be delivered in?

Summary

- If required, capacitors or reactors should remain connected during a fault and / or post fault
- Equipment should be capable of meeting 1 second response as currently defined in GB Grid Code
- Equipment should be capable of Repeatable, Consistent, Predictable and Continuously Available operations which are quicker than DAR time scales
- Equipment should support the volts to 0.85% post fault within <2.5 seconds to prevent cascade tripping of generation
- Requirements should be consistent with RfG

Discussion

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- What are the next steps?
- Consider possible solutions and report on
  - What improvement in performance can be achieved?
  - What is the impact on cost?
  - What time frames can any solution be delivered in?
- Identify definitive DAR and Reclaim times used by GB TSO’s and DNO’s
- Draft to proposed changes to the GB Grid Code