Hybrid STATCOM / SVC
Workgroup 7th August 2014

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National Grid – TNS Technical Policy

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Agenda

- Summary from previous meeting
- Actions from previous meeting
- NG Technical Specification - SVC's under fault conditions
- Storm Data
- DAR Times
- Questionnaire
- Requirements for Generators (Further Observations)
- Additional Study Work
- Summary
- Discussion

Summary from Previous Meeting

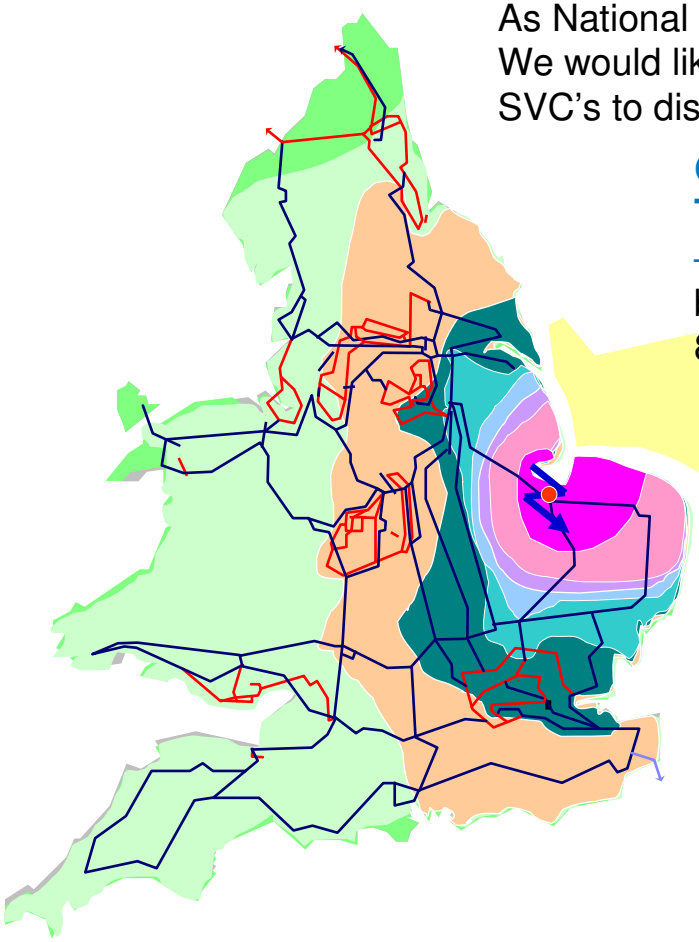
- If required, capacitors or reactors should remain connected during a fault and / or post fault
- Equipment should be capable of meeting 1 second response as currently defined in GB Grid Code
- Equipment should be capable of Repeatable, Consistent, Predictable and Continuously Available operations which 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

Actions – From the Minutes

- 39. ACTION – MB to work with RI and AJ to develop a questionnaire which is to be used to produce an indicative list of the technology that could meet the system requirements. To include within this the cost associated with any additional technology requirements.
- 43. ACTION – RI and AJ to complete more information to fully quantify the system need in the previous described circumstances, particularly in relation to DAR times for all TSO's (Transmission System Owners) and DNO's (Distribution Network Owners).
- 45. ACTION – RI and AJ to look into incident reporting and data logs for more detail regarding DAR with a view to better understand the operational challenges and clarifying the system requirements. – Tejas Badami
- 47. ACTION – RI and AJ to produce a survey for manufacturers and developers to understand the limitations and cost implications associated with improvement of the various alternative technologies.
- 48. ACTION – Manufacturers to look at the information that they are able to provide to ensure survey can be answered in a useful manner.
- 49. ACTION – RI and AJ to clarify the requirements for FRT (Fault Ride Through), looking at National Grids internal technical specifications and use these as an initial base to start to draft technical requirements.
- 52. ACTION: CH arrange doodle pole to establish availability

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.



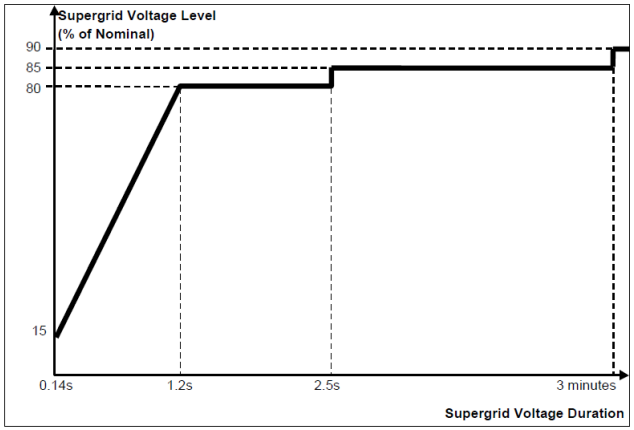
As National Grid doesn't switch its own capacitors out during fault conditions. We would like to understand why is it necessary for some Hybrid STATCOM / SVC's to disconnect capacitors during faults?

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**



NG Technical Specification – SVC's under fault conditions (TS.2.11)

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2.1.2 Short Term Capability and Rating

a.) General

Suppliers shall declare the short time capability of the SVC in the capacitive range.

In the inductive range the SVC shall be rated for continued operation at 1.3 per unit primary voltage for one second following and followed by operation at the maximum inductive capability. For voltages exceeding this magnitude and duration it is expected that control action will reduce compensator loading in preference to a protective trip. The short time capability of the SVC in the inductive range shall be declared by the Supplier.

b.) Requirements During Low Voltage Disturbances

1. For system voltages between the minimum continuous SVC operating voltage and 0.8 pu, the SVC shall continue generating MVAr's for at least 20 minutes. After this 20 minute period the SVC output can be reduced to zero MVAr's but the main SVC circuit-breaker shall not be opened.

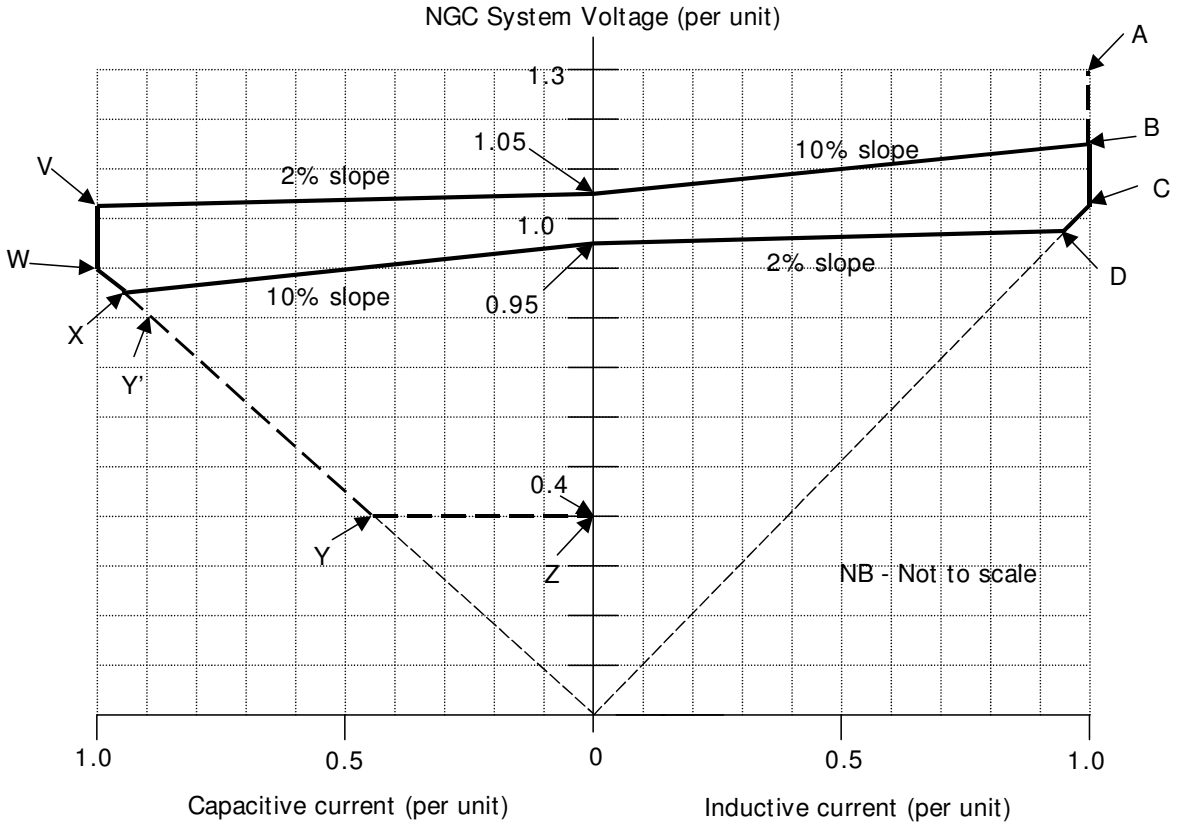
2. For system voltages between 0.8 pu and 0.4 pu, the SVC shall continue generating MVAr's for at least 1.5 seconds. The SVC circuit-breaker shall not open at any time that the system voltage is above 0.4 pu.

c.) For system voltages below 0.4 pu the SVC shall perform as follows:-

- for occurrences lasting less than 0.5 seconds the SVC shall be capable of generating MVAr's in accordance with pre-excursion control set points and targets immediately the system voltage returns to, or exceeds, 0.4 pu.
- for occurrences lasting between 0.5 seconds and 1 hour the SVC circuit-breaker shall not open; it shall be capable of generating MVAr's in accordance with pre-excursion set points and targets within 1 minute of the system voltage returning above 0.4 pu.
- for occurrences lasting more than 1 hour the SVC is permitted to open its circuit-breaker if it would be unsafe to re-apply voltage to the SVC; this condition shall be alarmed.

Any premium applied by National Grid at the Tender assessment stage due to the enhanced MVAr's generation performance of the SVC at low system voltages when compared to the MVAr's generation capability of an equivalent constant impedance device will be detailed in the SDS.

FRT Capability of NG SVC's



Notes:

A1 **The area enclosed within the solid lines (i.e. the area VWXDCB) is the required continuous operating region.**

A2 **Point W is the capacitive design point. Point C is the inductive design point. These will be specified in the SDS.**

A3 **Line AB is the one-second inductive voltage rating point (maximum value 1.3 pu, see clause 2.1.2 (a)).**

A4 **Lines ABCD and VWXY'YZ define the minimum Mvar output requirements at the extremes of the operating characteristic. Any premia applied at the Tender assessment stage for SVC Mvar output capability in excess of these minimum requirements will be detailed in the SDS.**

A5 **The line XY' is the 20 minute Mvar generation requirement of clause 2.1.2 (b)(i). The line Y'YZ is the 1.5 second Mvar generation requirement of clause 2.1.2 (b)(ii).**

Storm Data & Logging

National Grid Data Logging Facilities

- Data Historian
- Discrete Data Loggers etc.
- Faults Data Base

- **Data Historian**
  - Low Time Resolution
  - Very Large Data Base with Limited Search Facilities
- **Discrete Data Loggers / Dynamic System Monitors & Fault Recorders**
  - Connected at specific & limited monitoring points on the network
  - Variety of models & makes, operated by variety of different personal – limited access
  - No or very limited switch status information
  - Data regularly overwritten
  - In some case data only recorded when trigger criteria are met
- **Faults Data Base**
  - Manually Created Records
  - Limited Data Captured

Faults Database - 18/07/14

ENCC Report: Date: 18/07/2014 Time: 05:15:00

Suspect lightening, DAR from WARL. Closed manually at ELST

Multiple trips during lightning storm

- Following a lightning storm travelling West to East across Southern England the following events occurred:
- 00:54 hrs Trip and DAR of Fleet - Lovedean 1 circuit
- 02:31 hrs Trip & DAR of East Claydon - Leighton Buzzard - Sundon circuit coincident with DidcotB5 generator, and Culham Jet X110.
- Culham Jet were not taking demand at the time. Supplies are available awaiting confirmation from Culham Jet before restoration.
- 03:10 hours Trip & DAR of Barking – Northfleet – West Thurrock 2 circuit
- 03:11 hours Trip of Pelham – Wymondley circuit remains out of service
- 03:12 hours Trip and DAR of Kemsley – Littlebrook – Rowdown – Beddington 1 circuit coincident with Grain X190 which was providing station supplies.
- 05:14 hours Elstree – Warley 1 Trip and partial DAR charging from Warley closed manually at Elstree at 05:19

Faults Database - 18/07/14

ENCC Report: Date: 18/07/2014 Time: 03:57:00

Trip close trip

Cct remains out of service

Suspect lightening

conductor damage confirmed by / over M62

ETAM advise Top phase hanging below bottom phase on tower 2PA053 adjacent to M62 following overnight TRIP – DAR – TRIP

DAR of adjacent circuit (STAL-ROCH) switched out at site request.

Circuit Trips Overnight During Lightning Storms

- At 21:23hrs on Friday 18th July the Beddington-Rowdon-Littlebrook-Kemsley No.1 400kV circuit tripped & successfully DARd. A lightning storm was passing across South East England at the time.
- At 03:57hrs the Elland - Stalybridge 275kV circuit & Elland Mesh Corner 4 / SGT4 tripped. The DAR at Elland attempted to recharge the circuit but S30 re-tripped on closure. The Elland - Stalybridge circuit then auto - isolated at Elland and Mesh Corner 4 was subsequently restored via DAR. Elland SGT4 LV breaker 480 failed to reclose and was manually restored on-load at 04:05hrs.
- The Elland – Stalybridge circuit remains out of service pending further site investigation.
- At 03:59hrs the Bredbury-Stalybridge 275kV circuit & Bredbury Mesh Corner 3 / SGT3 tripped and successfully DARd.
- Lightning activity was evident in the vicinity at the time of both trips.

Following trip of Elland – Stalybridge circuit ETAM found top phase tension conductor parted on tower ZPA53 causing span to drop. Tower is in proximity to M62. However M62 remains open, local access has been restricted and repairs are being progressed.

DAR and Reclaim Times

- National Grid
  - DAR Time – Typically ≥15 10s (Trip Reset Times) + 5s (deadline charge)
  - Reclaim 4 – 20 Seconds (Typically 4secs)
- Scottish Power
  - Dead Time – >15 seconds
  - Reclaim Time – 4 seconds
- SHET (SSE)
  - Dead Time – 10 seconds
  - Reclaim Time – 2 to 5 seconds

Questionnaire (Slide 1 of 3)

Hybrid STATCOM / SVC Questionnaire

1. Following the Hybrid STATCOM / SVC workgroup meeting held in May 2014, it was agreed that a questionnaire would be sent out to all participants to establish their ability to satisfy a range of technical performance requirements and quantify any cost implications. If you can complete the questionnaire below this would be very much appreciated:
2. Can your Hybrid STATCOM / SVC equipment (as currently offered in GB) meet our current interpretation of the least onerous RfG requirement for t1 i.e. on a repeatable basis, achieve more than 90% leading or 90% lagging of its rating within 5 seconds (see “Note 1” for further clarification)? If not please describe any limiting factors and the available performance.
3. Can your Hybrid STATCOM / SVC equipment (as currently offered in GB) meet the current GB Grid Code requirement (CC.A.7.2.3) of Unity to 90% Leading or Lagging power factor in less than 1 second?
4. What is the cost / MVAr of the solution(s) you currently offer in the GB (cost should include typical commissioning and installation costs).
5. In order to ensure we are comparing like solutions, please confirm whether or not the solution use mechanically switched elements.
6. What improvements in performance can be achieved by 2017 and what is the impact on the answers to questions 3 and to question 4?

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Questionnaire (Slide 2 of 3)

Note 1 – We interpret RfG (Requirement for Generators) as requiring all STATCOM's and SVC's to produce the required reactive power output (as defined by the set point, feedback voltage at the grid entry point and droop setting) to within 5% at all times, the only exception being immediately following a change in the set point or the voltage feedback signal. In the event that the set point or voltage feedback signal is changed the STATCOM or SVC must produce and maintain reactive power to within ±10% of the new steady state value within t1 and then must return to an operating tolerance of less than 5% within t2. For the least onerous value of t1, which is 5 seconds, this would require the STATCOM or SVC to be capable of moving repeatedly moving from 90% leading to 90% lagging of rated MVAr and visa versa every 5 seconds. For example: The STATCOM / SVC must be capable of moving from 90% leading to 90% lagging of rated MVAr and visa versa every 5 seconds for an hour at a 50% duty cycle i.e. 360 times or any lower frequency as demanded by changes in set point or voltage feedback.

Note 2 – We understand that manufacturers may consider the above information to be commercially sensitive. When presenting results we will group them and not give the manufacturers name and will only present relative cost information i.e. % change.

Note 3 – If you questions regarding the above please contact either Antony Johnson or Richard Ierna at National Grid.

Questionnaire (Slide 3 of 3)

Note 4 – The relevant section of RfG is given below for reference:

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 1.05pu in steps no greater than 0.01pu 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.

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RfG Further Observations – 1 of 4

RfG States:

*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.*

- Believe the above requires a generator to achieve the required reactive power to within 5% at all times with the only exceptions being after a change in Setpoint or Voltage Feedback (e.g. after fault or disturbance).
- Excursions outside of the 5% are timed limited by t1 (1 – 5 secs) and t2 (5 – 60 secs at 10% of target).
- This require repeatable performance.
- However within t1 only **90% of the change** in reactive power must be achieved – DOES THIS ALLOW FOR RELAXING OF THE REACTIVE POWER PRODUCED?

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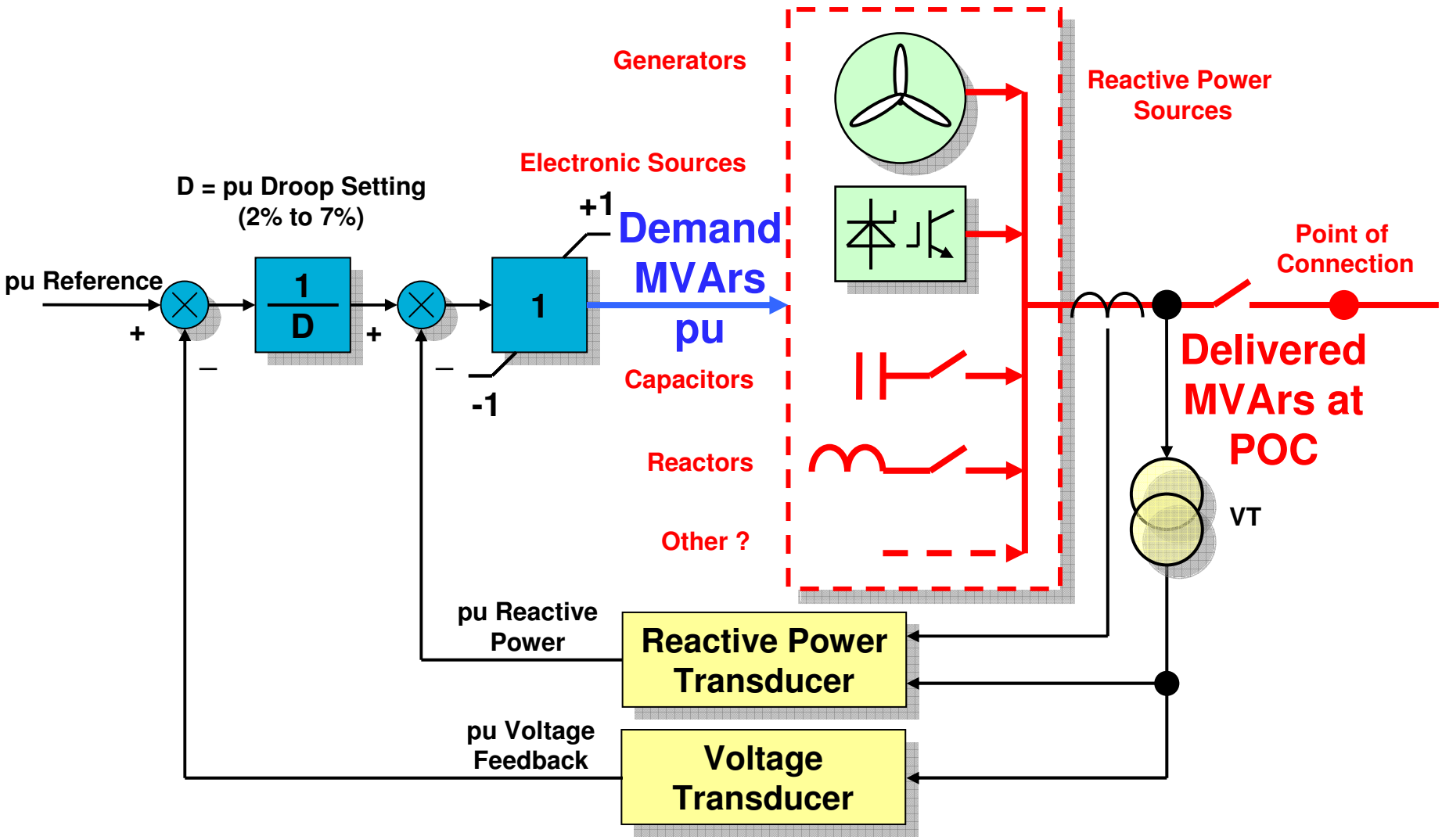
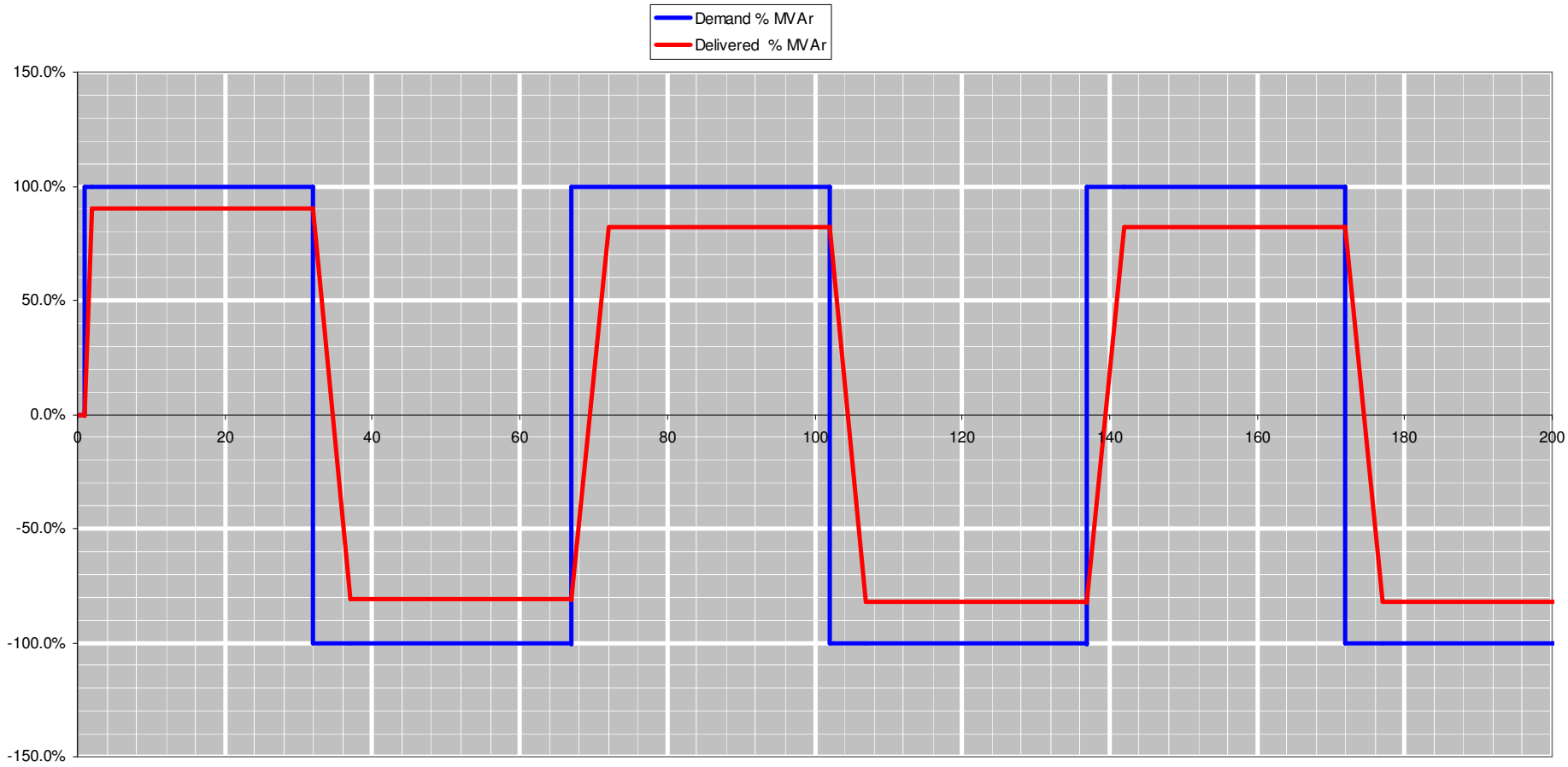
RfG Further Observations – 2 of 4



RfG Further Observations – 3 of 4



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RfG Further Observations – 4 of 4

Further Cases to Consider:

- Above Slide Shows
  - t1 = 5s, t2 = 60s & steady state = 30s
- Additional Cases (Talk Through)
  - t1 = 5s, t2 = 15s & steady state = 30s
  - t1 = 5s, t2 = 60s & steady state = 5s
  - t1 = 5s, t2 = 60s & steady state = 0s
  - t1 = 1s, t2 = 60s & steady state = 5s

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Additional Study Work

- Previous Studies Demonstrating Need Case
  - South Coast Study
  - Spalding North, Bicker Fen Walpole
  - Heddon Circuit Trips and DAR
- Started Considering the Effects of Limited Reactive Capability in North of Scotland
  - Voltage Collapse Scenario
  - Studies using dynamic GB model time consuming - Further Investigation Required

Summary

- NG Technical Specification – SVC's under fault conditions
  - Full capacitive capability available down to 0.95pu Volts
  - Full inductive capability available up to 1.3pu Volts for 1 sec
  - For voltages between min cont. and 0.8pu for ≤20s, reactive current proportional to volts
  - For voltage between 0.8 to 0.4pu for ≤1.5s, reactive current proportional to volts
  - For voltage below 0.4pu for ≤0.5s must immediately resume reactive output on ≥0.4pu
- Storm Data
  - Recent storms demonstrate 3 consecutive switched events in a 3 minute period
- DAR Times
  - Typically >10sec
  - Reclaim time 3-20secs
- Questionnaire – Discussion
- Requirements for Generators (Further Observations)
  - With t1 set 5s & t2 at 60s can permit ~82% of capability for first minute
  - GB Grid Code and GDP currently requires t1 to be 5secs for full range and 1sec for 50%.
- Additional Study Work – Will produce further study case if required

Discussion