Constant Terminal Voltage

Working Group Meeting 4
19th September 2014

Overview

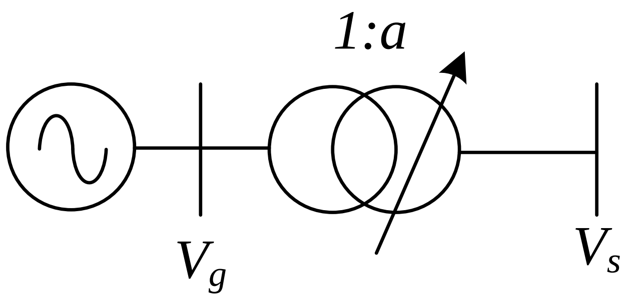
- Options summary
- System under investigation
- Options analysis
- Discussion

Options

- Option 1 – Constant Terminal Voltage controlled to 1 p.u with full Transformer Tapping
- Option 2 - Adjustable Terminal Voltage with a limited Transformer Tapping Range
- Option 3 – Limited Transformer Tapping Range only

System under consideration

- 1770MW Unit (1097/-582 MVAr range)
- 2100MVA Transformer
- 0.13pu transformer reactance
- No transformer copper losses and no tap dependant reactance



System under consideration

- Following last meeting, further study work has shown complete agreement between equations, Matlab models, and Power Factory simulations.

$$a = \frac{V_s V_g}{X_{tr}\sqrt{\left(\frac{V_g^{\,2}}{X_{tr}} - Q_g\right)^2 + P_g^{\,2}}}$$

- Range for off-nominal turns ratio:
  - 1:1.120 to inject 1097MVAr at 1.05pu
  - 1:0.912 to absorb 582 MVAr at 0.95pu

$$\frac{\partial Q_g}{\partial a} = \frac{V_s^2 V_g^{\,2}}{a^2 X_{tr}\sqrt{V_s^2 V_g^{\,2} - a^2 X_{tr}^{\,2} P_g^{\,2}}}$$

- 0.20% voltage/tap to meet the +/-25MVAr tolerance.
  - Maximum MVAr step is 38MVAr

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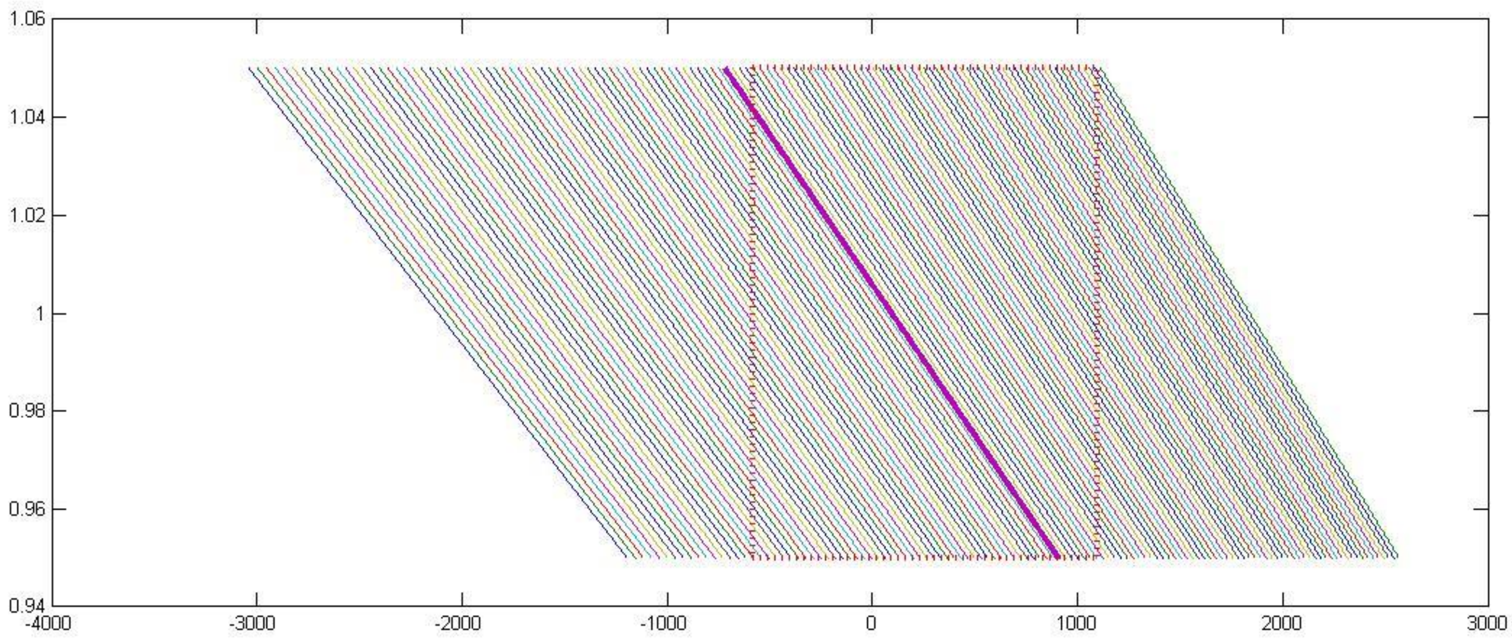
Option 1

- 1.0pu Terminal Voltage with full tap range.

- +60/-44taps are required to meet the full reactive range.



Option 1

- Feasibility of the 0.2% voltage/tap
- Implications of the large number of taps on
  - Capital cost
  - Reliability/availability (and costs associated with it)
  - Time to respond to an instruction
- Feasibility of having two tap changers in series (Coarse adjustment and fine tuning)
- Reducing MVAr tolerance to +/-80MVAr would allow provision of the full range of reactive capability with -19/+24taps
- Any change of MVAr should be considered in conjunction with the Grid Code/P28 restrictions on voltage step changes

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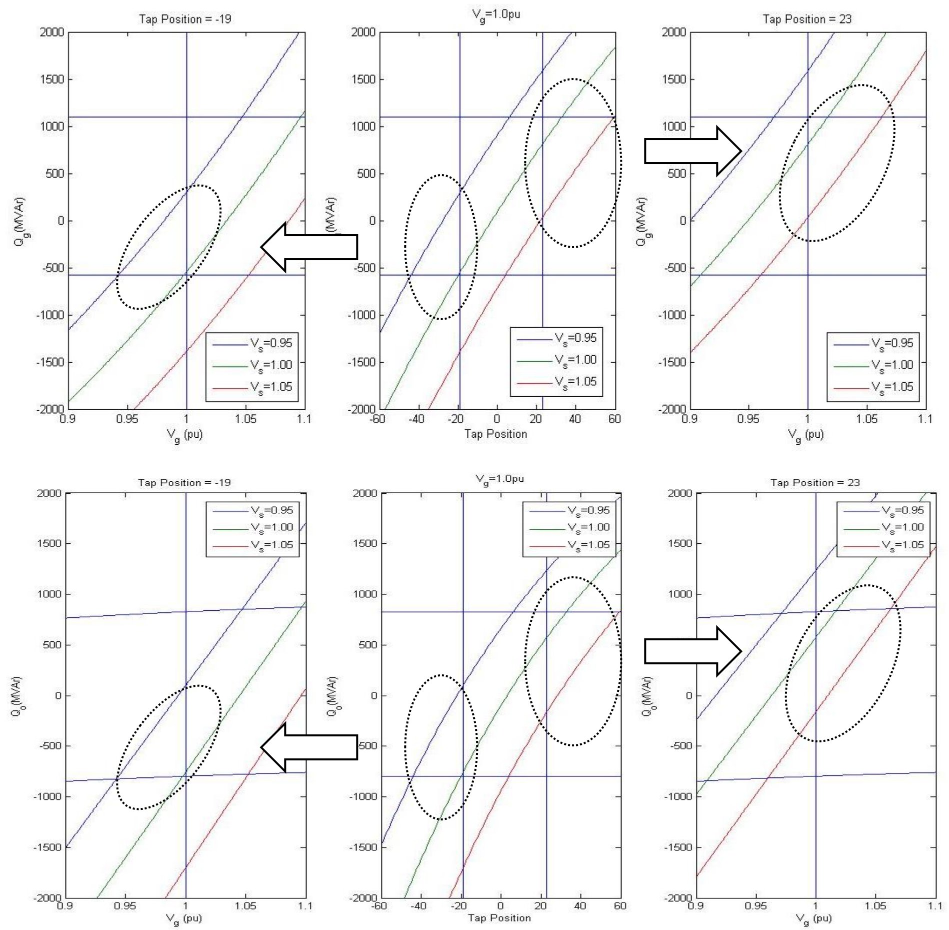
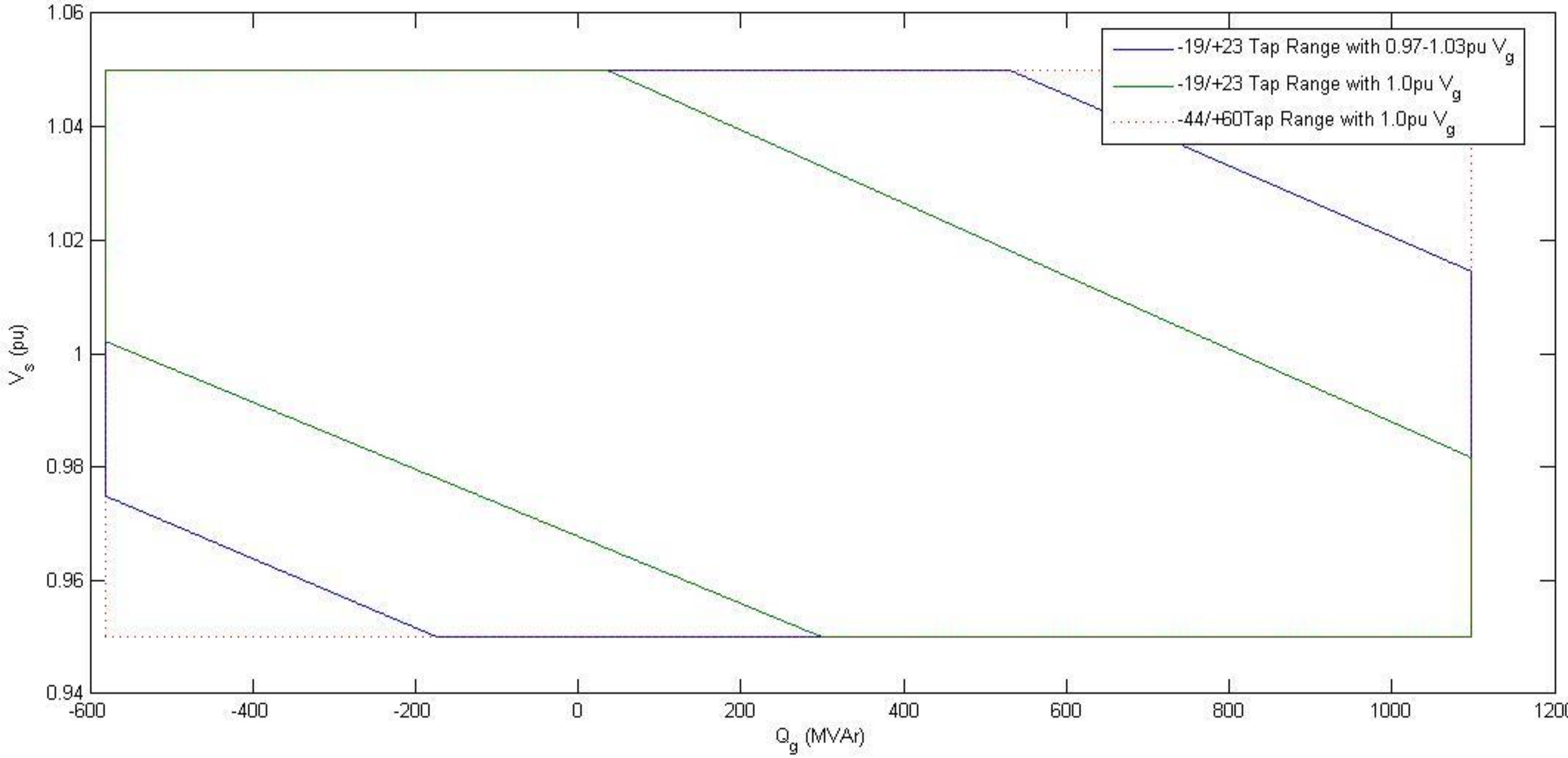
Option 2

- The upper figure shows the reactive power output of the generating unit
- The lower figure shows the reactive power delivered to the system
- The three curves in each plot correspond to 0.95pu, 1.0pu, and 1.05pu voltage at the grid entry point.
- Tap control is shown by the middle figures.
- Terminal voltage control at the upper tap is shown on the right
- Terminal voltage control at the lower tap is shown on the left



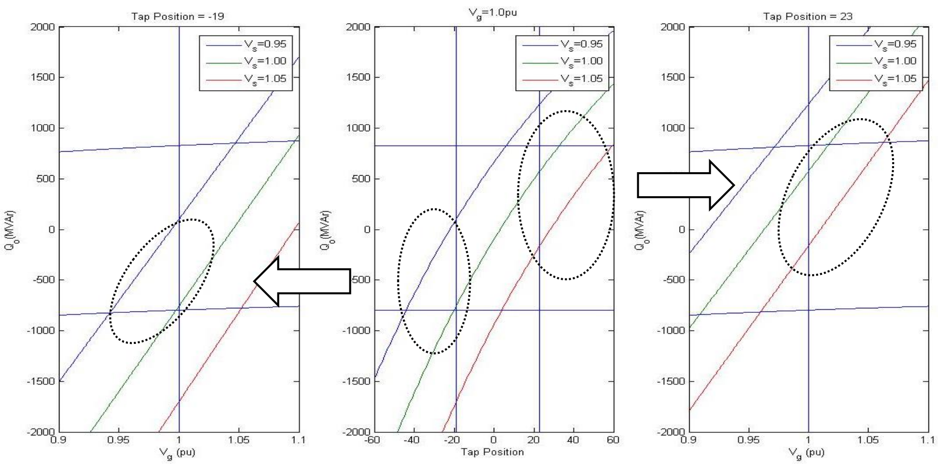
Option 2

- Limited tap range (+23/-19taps). 1.0pu terminal voltage at taps from -18 to +22. Terminal voltage controlled between +/-0.03pu at tap -19 and tap 22.
- The current Grid Code requirements are not met.



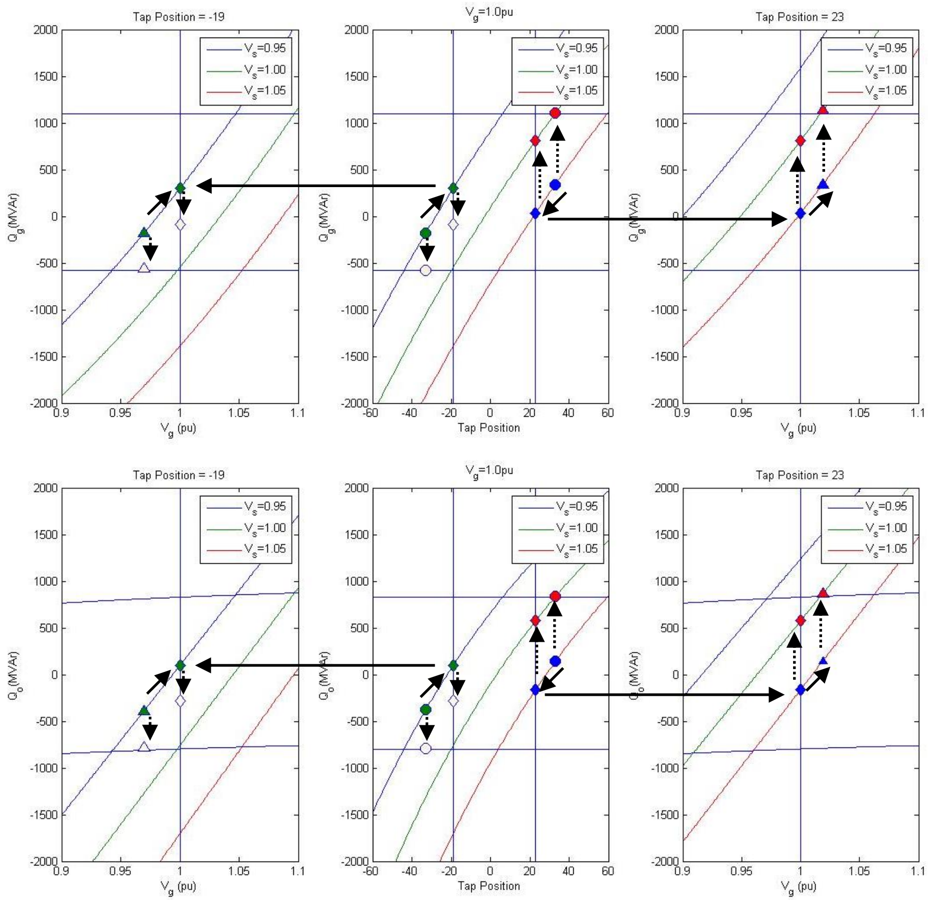
Option 2

- **<u>Implications on reactive range</u>**
- Terminal voltage will need to vary within +/-6.3% instead of 3% as originally thought to achieve full Grid Code requirement.
- Full reactive range available at the machine terminals.
- Marginal gain on the reactive range available at the Grid Entry Point



Option 2

- **<u>Implications on post fault response</u>**
- Start with a tap position that falls outside the restricted tap range.
- Limit the tap range and maintain a1.0 pu terminal voltage.
- Change the terminal voltage to restore the original reactive power output.
- In the three cases, compare the response of reactive power output to a change in the system voltage



Option 2 – Implications on post fault response

- **<u>Implications on post fault response:</u>** Lagging MVArs
  - Qg response: Improves for operation at lower tap position and for operation at higher terminal voltage
  - Qo response Improves for operation at lower tap position, deteriorates for operation at higher terminal voltage, varies for a combination of both – <u>there was an overall improvement in the case study here.</u>

	Pre fault Vs=1.05pu		Post fault Vs=1.0pu		Change	
	Qg MVAr	Qo MVAr	Qg MVAr	Qo MVAr	ΔQg MVAr	ΔQo MVAr
Point 1 Tap 33 Vg=1.0	341.21	140.07	1103.9	834.5	762.69	694.43
Point 2 Tap 23 Vg=1.0	35.117	-158.9	812.17	577.39	777.05	736.29
Point 3 Tap 23 Vg= 1.0188	341.21	147.41	1132.7	869.29	791.49	721.88

Option 2

- **Implications on post fault response:** Leading MVArs
  - Qg response: deteriorates for operation at higher tap position and for operation at higher terminal voltage
  - Qo response deteriorates for operation at lower tap position, deteriorates for operation at lower terminal voltage, varies for a combination of both – there was an overall deterioration in the case study here.

	Pre fault Vs=0.95pu		Post fault Vs=0.973pu		Change	
	Qg MVAr	Qo MVAr	Qg MVAr	Qo MVAr	ΔQg MVAr	ΔQo MVAr
Point 1 Tap -33 Vg=1.0	-181.11	-377.08	-581.18	-796.03	-400.1	-419
Point 2 Tap -19 Vg=1.0	300	100.49	-88.554	-282.98	-388.6	-383.5
Point 3 Tap -19 Vg= 1.0188	-181.11	-389.62	-557.95	-784.8	-376.8	-395.2

Option 2

- **<u>Implications on transient stability:</u>**
  - Addressed by EdF presentation

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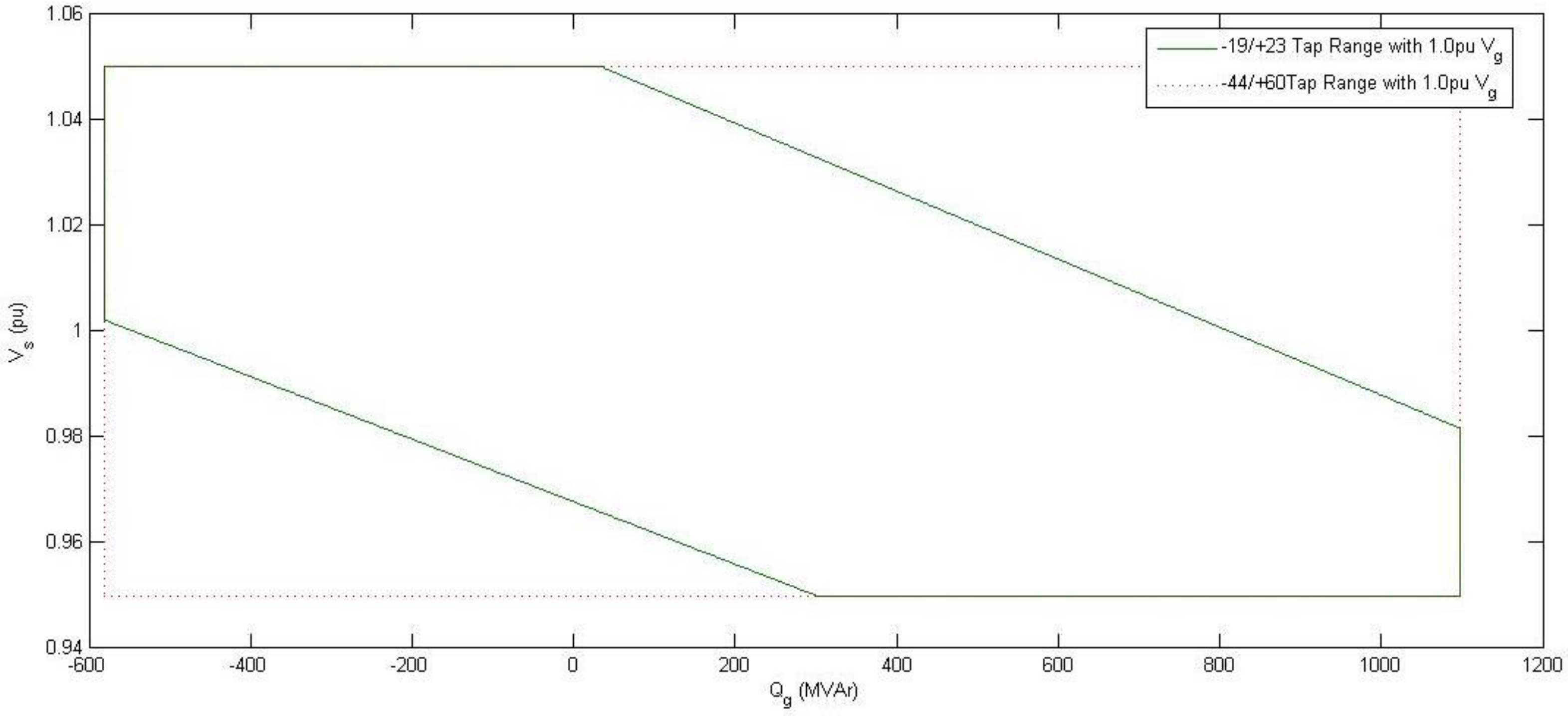
Option 3

- 1.0pu Terminal Voltage with limited tap range (+23/-19taps).
- **<u>The full reactive range is not available at 1.0pu voltage</u>**
- Reducing MVAr tolerance to +/-80MVAr would allow provision of the full range of reactive capability with -19/+24taps



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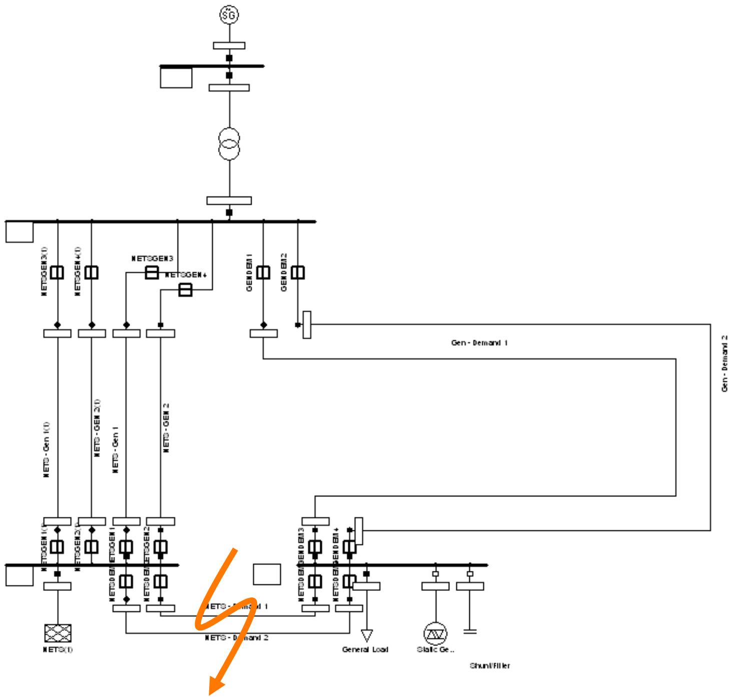
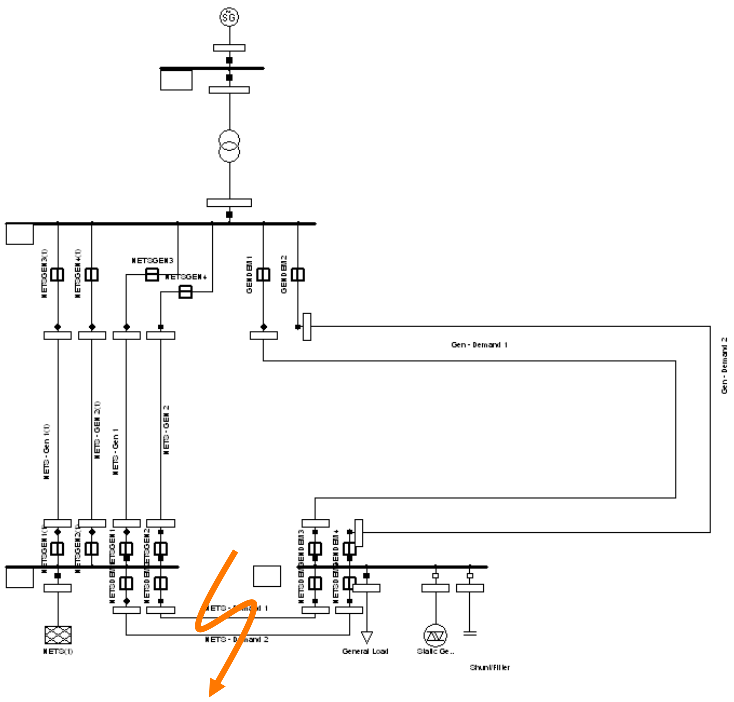
Option 3

- Not the favourite option as it reduces the reactive range available.
- Issue appears when a fault results in demand being supplied through a long OHL
- Post fault, preference is to supply the reactive demand from the generator rather than from the system
- Due to line length, the pu voltage at the generator terminals will need to be maintained at 1.05pu when the generator is delivering MVArs or at 0.95 when absorbing MVArs
- Records of Drax absorbing maximum MVAr at 388kV to bring high volts down in the North East
- An illustration of what the issue would be is provided
- Currently looking for further evidence



Option 3

- **<u>Illustration – MVAr Injection</u>**
- 200km line – maybe not a single line in reality but a stretch of substations with demand only and not a lot of reactive compensation
- High demand conditions
- Voltage at the system busbar needs to be kept between 1.04pu and 1.05pu.



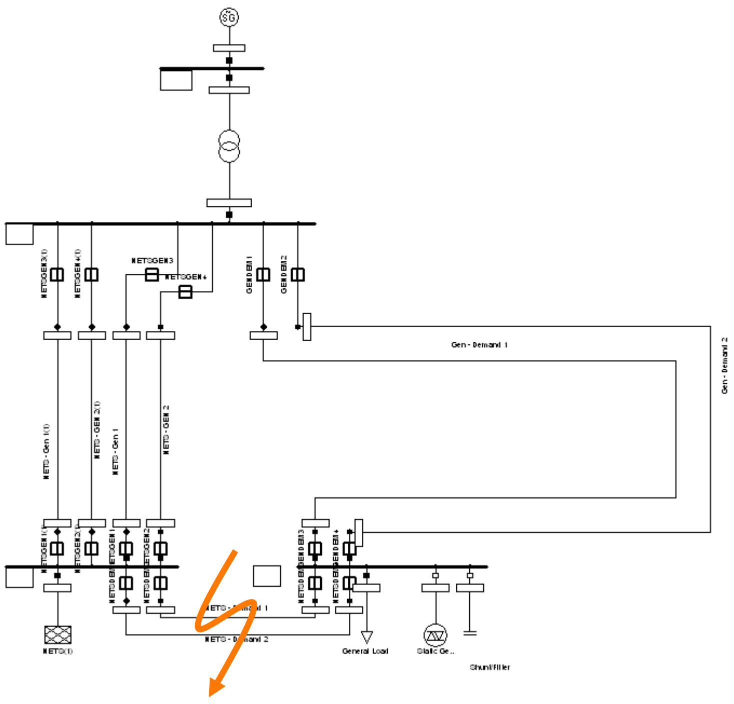
Option 3

- Voltage at the system busbar needs to be around 1.04pu.

  - Lower voltage levels would result in post fault voltage below 0.9pu at the demand busbar
  - 1.05 voltage level would indicate volts higher than 1.05pu deeper in the system

- 560MVAr generation at 1.046pu voltage is feasible.

- 1060MVAr generation at 1.05pu is preferred



Additional Consideration
Relaxing the 25MVAr tolerance

- Potential difficulty in setting up a reasonable voltage profile especially at minimum demand conditions.
    - *Tap hunting*
    - *Larger voltage excursions*
    - *Even larger voltage excursions just prior to minimum demand and maximum demand*
- Restrictions due to voltage step limit (1%).
- Additional investment (small STATCOMs/SVCs)
- Additional operational costs for reactive power instruction above the value instructed by the SO.

Discussion