Constant Terminal Voltage

Working Group Meeting 5
10th December 2014

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Overview

- Review of Actions
- Review of Options
- Relevant Study Work
- RfG Requirements
- Advantages and Disadvantages of each Option
- Preferred Option

Review of Actions

- Item 82 of previous minutes to be updated to make it more explicit. – Completed – see next slide
- AJ to establish if the standard study model uses constant power or constant impedance. – *Completed – The Standard Study model uses Constant Power (NB:- there is the option to use more detailed load models if the need arises).*
- BA to re-check simulations and examine the effect of varying the system strength. – *Addressed within the presentation*
- BA to check transformer ratio 1:0.912 should be 1:0.92 on slide 5 of previous presentation – *I stand by 1:0.912 – With 0.92, we will be around 11MVAr short at 0.95pu voltage – Happy to discuss with HM*
- BA to undertake further analysis on considering relaxing the ±25MVAr tolerance, in particular the impact on voltage levels. – *Ongoing*
- Identify the likely implications of Option 1 on any derogations not yet granted by Ofgem – *Discuss*
- NGET to further investigate options 2A and 2B in particular the boundary between the transformer tap range and the point at which Generator Terminal Voltage is used to control the HV Voltage – Completed – see subsequent slides
- NGET to start preparing a draft working group report. – *In progress*
- NGET to circulate a doodle poll for meeting dates in early / mid-November. – Completed – scheduled for 10th December

Action – Review Item 82 of Previous Minutes

- Initial draft

  HM suggested that the ±25MVAr tolerance should be omitted as, in his view, precision is not that critical and that the restriction on voltage step changes are sufficient. PN raised the point that reactive power payments are based on actual production. If this is very far off from the value instructed by NGET, some generators might be paid for a service that they were not required to provide.

- Suggested text

  HM suggested that the ±25MVAr tolerance should be omitted as, in his view, precision is not that critical and that the restriction on voltage step changes are sufficient. PN raised the point that reactive power payments are based on actual production and therefore if a Generator could not achieve the target MVAr value instructed by NGET, they could either be overcompensated (for generating more MVAr's than instructed) or undercompensated (if generating less MVAr's than instructed).

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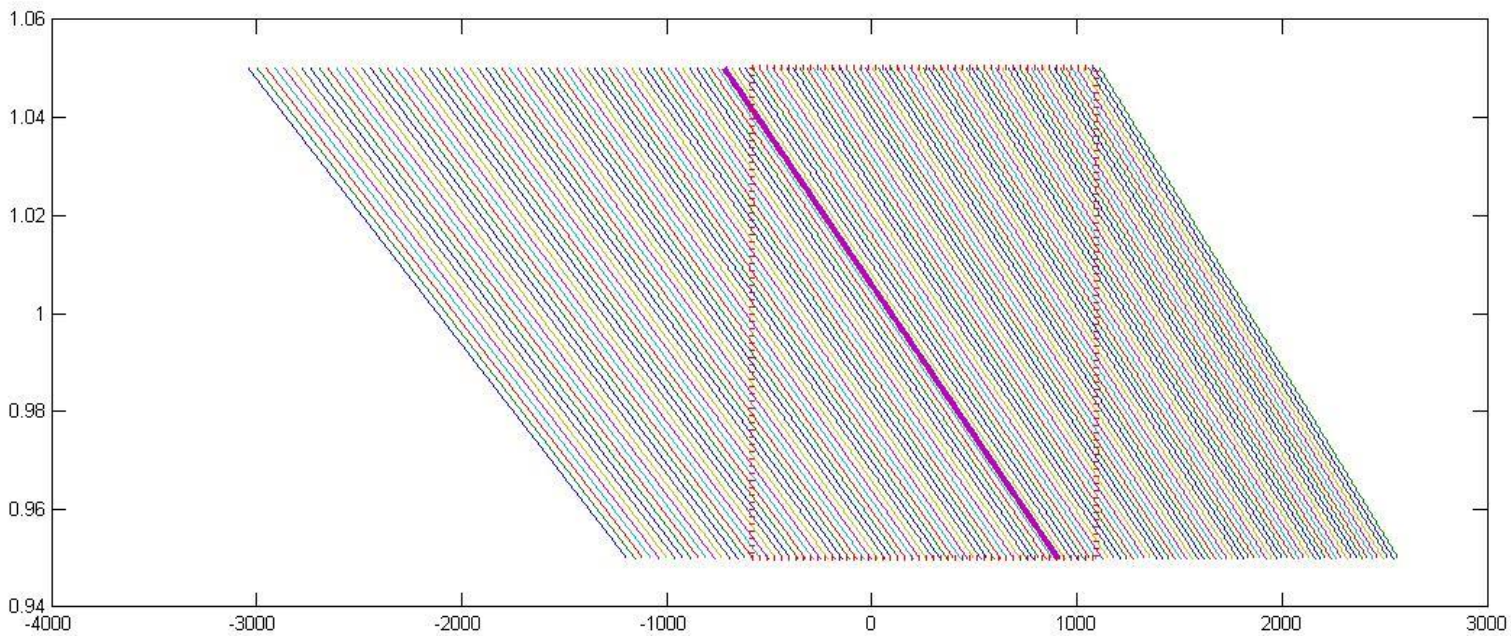
Review of Options

- Option 1 – Constant Terminal Voltage controlled to 1 p.u with full Transformer Tapping
- Option 2A - Adjustable Terminal Voltage at extreme ends of the range with a limited Transformer Tapping Range. Each Tap step limited to ±25MVAr. Generator terminal voltage controlled between 1.0p.u – 1.03p.u
- Option 2B – Adjustable terminal voltage and limited transformer tapping range. Tap step exceeds ±25MVAr but less then permitted voltage step change. Generator Terminal voltage controlled between 1.0p.u – 1.03 p.u to achieve target voltage required to the level of accuracy required.
- Option 3 – Limited Transformer Tapping Range only. Generator Terminal voltage fixed at 1.0p.u. Discounted at previous meeting.

Option 1

- 1.0pu Terminal Voltage with full tap range.
- +60/-44taps are required to cover the full reactive range – assuming the generator is connected to an infinite system.
- The actual tap range required is dependant on the short circuit

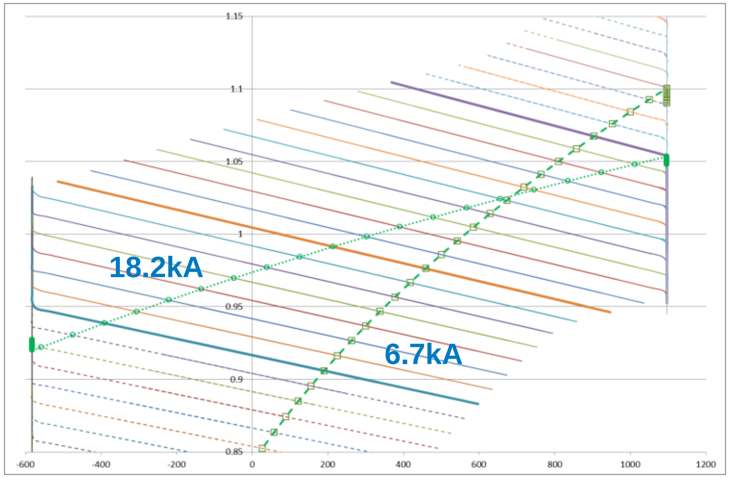


Option 1- Effect of short circuit level

- Reduction in short circuit level
  - reduces the MVAr step change
  - Increases the voltage step change

- No. of taps required is a function of system strength
  - Infinite system: +60/-44
  - 18.2kA: +19/-14
  - 6.7kA: +10/-8

- Assessment has to be on a case by case basis



Trajectory of operating point due to tap change actions for two different short circuit levels

1770MW machine

2100MVA transformer

1.25% voltage/tap

Option 1 – Information required to support/rule out the option

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- Is there any design restriction on tap steps? What is the smallest tap step we can reach?

- Need to quantify the 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)

Option 2

- Study cases modelled suggest that an increase in the terminal voltage target
  - increases stability margin, and
  - improves post fault steady state response; whereas

- a reduction in the terminal voltage target
  - reduces stability margin, and
  - makes post fault steady state response worse.

- Minimum terminal voltage target setting should be 1.0pu

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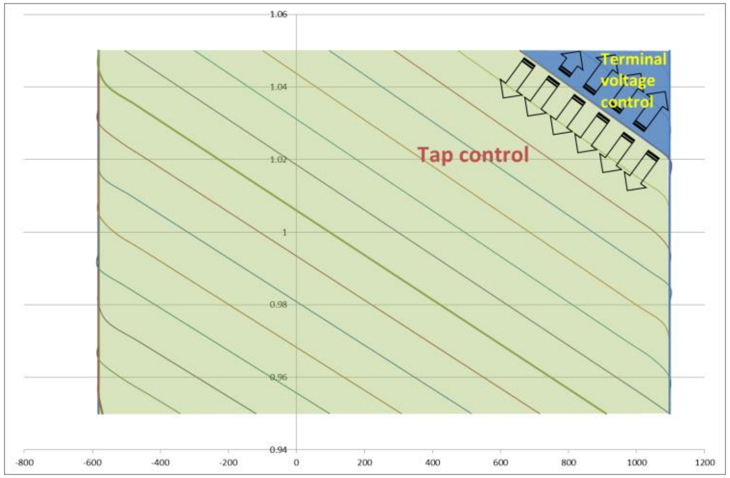
Option 2A

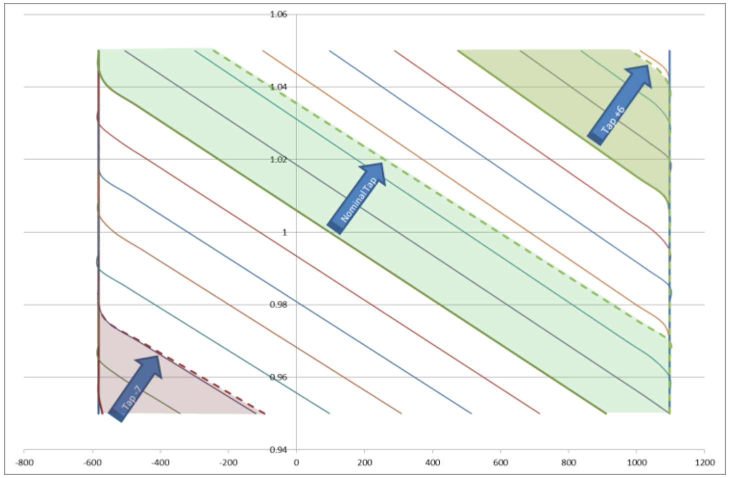
- The majority of the reactive range covered by varying the transformer tap position.
- The upper right corner of the reactive range covered by varying the terminal voltage target.
- Terminal voltage that is less than 1.0pu ruled out.
- Number of taps dependant on the range and the short circuit level.
- 17%reduction in tap range (and number of taps)



V_{min}	V_{max}	a_{min}	a_{max}	a_{range}	
1.0	1.0	1:0.912	1:1.119	0.207	100%
1.0	1.03	1:0.912	1:1.083	0.171	83%
0.97	1.03	1:0.937	1:1.083	0.146	71%

Option 2B

- Potentially less tap requirements
- Coarse taps (2.5% voltage/tap) may be adequate. However, in the example used, this is likely to cause a voltage step of more than 1%
- Better MVAr resolution is achievable – Subject to the resolution of voltage target
- Load flow algorithms need to be modified



Reactive range covered by altering the terminal voltage target

Range shown for Tap -7, Nominal tap, and Tap +6

Voltage range: 1.0pu to 1.03pu

1770MW machine

2100MVA transformer

1.25% voltage/tap

Option 3

- Option ruled out as it reduces the reactive reserves available to the system operator

The ±25MVAr tolerance

- Consequence of removing the requirements
  - Voltage step changes of up to 1%
  - Voltage precision is 4kV on the 400kV system.

- Difference between 1x1800MW unit and 3x600MW units connected to the same bar.

- Additional operational costs for the System Operator.

- Reduced costs for generators

RfG Requirements – Based on 14 January 2014 Version

- Article 12 (b) – With regard to the Voltage control system, a Synchronous Power Generating Module shall be equipped with a permanent automatic excitation control system in order to provide constant Alternator terminal Voltage at a selectable Setpoint without instability over the entire operating range of the Synchronous Power Generating Module

Option 1: Advantages / Disadvantages

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- Constant Terminal Voltage controlled to 1 p.u with full Transformer Tapping

Advantages	Disadvantages
i. Generator Terminal voltage continuously controlled to 1p.u - business as usual with no additional operational uncertainities. ii. No implications on stations auxiliaries. iii. Maintains current Dynamic Reserve provision post fault. iv. Maintains Stability margin v. No change required to algorithms/business procedures	i. Potentially more expensive than other options (eg Transformer required with excessive tapping range). ii. References to BCA – Loss of Transparency iii. May not fully address Derogation issue (Decision will need to be made on a case by case basis) iv. Slow response to reactive power instructions v. Potential reliability/availability issues for generator transformers

Option 2A: Advantages / Disadvantages

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Adjustable Terminal Voltage at extreme ends of the range with a limited Transformer Tapping Range. Each Tap step limited to ±25MVAr. Generator terminal voltage controlled between 1.0p.u – 1.03p.u

Advantages	Disadvantages
i. Limited reduction in tap range with potentially saving on the cost of the Generator Transformer. ii. Preserves the total reactive capability (ie operating envelope still maintained) iii. Slight increase to the reactive range available on the HV side of the transformer iv. Improvement of the stability margin with terminal voltage higher than 1.0pu v. Slight improvement in reactive power post fault response at the generator HV terminals with terminal voltage above 1.0pu vi. Potentially addresses derogation issue	i. More complex to define minimum requirements of Generator transformer tapping range and Generating Unit target voltage range. ii. Modelling issues need to be considered – potential change to algorithms/business procedures. iii. Further reduction in the number of taps require operating at terminal voltage beyond +/-3% iv. Slight reduction in reactive power post fault response at the generator HV terminals at terminal voltage below 1.0pu v. Reduction of the stability margin with terminal voltage below 1.0pu

Option 2B: Advantages / Disadvantages

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Adjustable terminal voltage and limited transformer tapping range. Tap step exceeds ±25MVAr but less then permitted voltage step change. Generator Terminal voltage controlled between 1.0p.u – 1.03 p.u to achieve target voltage required to the level of accuracy required

Advantages	Disadvantages
i. Significant reduction in the number of taps required (subject to step voltage change restrictions) with potentially saving on the cost of the Generator Transformer. ii. Preserves the total reactive capability (ie operating envelope still maintained) iii. Potentially able to provide MVAr tolerance that is better than ±25MVAr iv. Slight increase to the reactive range available on the HV side of the transformer. v. Improvement of the stability margin with terminal voltage higher than 1.0pu. vi. Slight improvement in reactive power post fault response at the generator HV terminals with terminal voltage above 1.0pu.	i. Modelling issues need to be considered – potential change to algorithms/business procedures. ii. Potentially does not address derogation issue iii. Slight reduction in reactive power post fault response at the generator HV terminals at terminal voltage below 1.0pu iv. Reduction of the stability margin with terminal voltage below 1.0pu

Option 3: Advantages / Disadvantages

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Limited Transformer Tapping Range only. Generator Terminal voltage fixed at 1.0p.u.

Option discounted at previous meeting.

Advantages	Disadvantages
i. Potentially cheaper Transformer with lower tapping range	i. Very limited reactive range available even when the voltage at the Grid Entry Point is 1.0pu. ii. Likely to result in potentially greater costs to both NGET and Generators

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Preferred Option

- Although there are still a number of issues to be resolved, Option 2B would appear to be the best option going forward
- Option 3 was discounted at the previous meeting
- Option 1 would be a costly option for very large Synchronous Generators up to 2100MVA potentially requiring over 100 taps
- Option 2A provides limited benefits with a significant level of uncertainty.
- Option 2B provides the most attractive option but modelling and operational issues need to be completely understood.

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Discussion