# Minutes

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| Meeting name : | GC0028: Constant Terminal Voltage |
| Meeting number: | 5 |
| Date of meeting : | Wednesday, 10 December 2014 |
| Time : | 10:00 – 14:00 |
| Location : | National Grid House, Room: D2.4<br>Warwick Technology Park, Gallows Hill, Warwick, CV34 6DA |

## Attendees

| Name | Initials | Company |
|---|---|---|
| Graham Stein | GS | National Grid (Chair) |
| Antony Johnson | AJ | National Grid |
| Bieshoy Awad | BA | National Grid |
| Franklin Rodrick | FR | National Grid |
| John Norbury | JN | RWE |
| Paul Newton | PN | EON |
| Herve Meljac | HM | EDF |
| Philip Belben | PB | Horizon |
| Lorna Short | LR | RWE |
| Touleng Lochungvu | TL | Nugen |
| Karim Karoui | KK | GDF |

## Introductions & Apologies

1. GS welcomed everyone to the meeting and the attendants introduced themselves. GS explained that the purpose of the meeting was to review the work completed to date and identify if a conclusion could be reached.

## Minutes of last meeting

Comments on minutes:-

2. GS discussed the draft minutes from the last meeting. PB advised he had one comment relating to item 142 suggesting rephrasing “restricted number of taps to restricted tap range”.

3. JN advised he had one comment relating to item 144 and suggested to change the wording to JN suggested drafting a workgroup report would be helpful. AJ explained that keeping timescales in mind, it was would be better to draft the workgroup report and send it to the workgroup members for comment. It was suggested that the aim was to forward the final workgroup report to the GCRP in March 2015.

4. No other comments were provided and subject to the above changes, the minutes from the last meeting were accepted as final.

## Option and Study Work – NGET Presentation

**a) Review of Actions**

AJ took the group through the actions.

5. Item 82 from the June 2014 meeting was discussed. AJ explained the revised text and outlined how instructions are issued to Synchronous plant for voltage control purposes. He advised that National Grid Control Engineers will generally issue MVAr instructions to Generators. It will then be for the Generator to adjust the tap changer to achieve the reactive power required at the Connection Point. .

   **Action: AJ to speak to contracts team to find out about target MVAr values.**

6. KK raised a question about whether a generator is responsible for producing MVArs or keeping the voltage level maintained. AJ explained that a synchronous generator needs to tap the generator transformer to provide MVAr output as instructed by National Grid. The reactive power output of the generator would then be expected to vary as the Transmission System voltage changed. JN explained that there are different options allowed in the Grid Code for generators to be instructed to provide reactive power.

7. JN suggested that only Gensets instructed to provide reactive power via a "MVAr Output" have to comply with the +/- 25MVAr tolerance. He advised this is more of an operational requirement under BC2.A.2.6 rather than a design requirement applicable to all generating units. JN suggested that if NGET need this tolerance range from all synchronous generating units then other options to meet this should be available to the generators.

8. BA discussed the action on transformer ratio. He advised 1.9.02 should be the correct option. He also advised that further study work had been completed to investigate the impact of Generator terminal voltage control over a wider tap range

9. GS highlighted that it would be an advantage, although not necessary, if the solution proposed by the workgroup addresses outstanding derogations issue.

## Review of Options

10. BA explained option 1. He advised that to have 1.0pu terminal voltage with full tap range would require a total of 110 taps when the Generator was connected to an infinite bar. BA explained that the numbers were based on a 1770MW generator with a 2100MVA transformer.

11. BA summarised the effect of short circuit levels. It was noted that if the Generator was connected to an infinite system with a tap step of +/-25 MVAr then 110 taps would be required. BA then showed further analysis showing how the number of taps falls if the system strength is then reduced.

12. PN raised a question about who would specify the maximum strength of the system? AJ advised this would be specified in the Bilateral Connection Agreement.

13. HM commented that with a +/-25 MVAr range we are deriving technical requirements from business requirements. He added that as System Operator National Grid should not think about the reactive power but the voltage levels across the system. AJ explained that as System Operator, National Grid has a statutory obligation to manage voltage levels between limits specified in the Security and Quality of Supply Standards and to control system frequency.

14. HM made a comment about the MVAr tolerance requirement and how this will change based on the location and the system strength at the connection point. He also noted that as more Generators connect to a site, the fault level will change which affects the number of generator transformer taps required.

15. GS highlighted that for Option 1 it was important to define the combined requirement for a 1.0pu terminal voltage and a +/-25 MVAr tolerance between each tap.

16. PN suggested that NGET should produce a graph showing the effects of different short circuit levels to show the effect of an infinite system, a fault level of 63kA and a fault level of 18.2kA. PN also noted the 13% impedance used in the calculation on the number of taps.

    **Action: NG to produce a graph with different short circuit levels.**

17. KK highlighted that larger generators will need to use bigger transformers which will make a achieving a tolerance of +/-25 MVAr more difficult.

18. BA requested suggestions from workgroup members to provide evidence to support their argument that having large number of taps is not practical.

## Tap Changer Issues – Solution Mastery Ltd Presentation

19. PB delivered a presentation on tap changer issues.

20. PB explained the principle of a simple tap changer noting that if the space available to attach the tap is very limited, external windings are used.

21. PB explained the principle of a conventional tap with a buck / boost winding. In the example shown a diverter is required on the tapping winding but not on the other switch.

22. PB explained that each tapping interval should be a whole number of turns. He added that larger transformers have a larger voltage per turn and fine tapping may be impossible.

23. PB suggested solutions for the tapping issue. He highlighted that if the tapping winding is taken out and put in a smaller transformer, then the problem can be resolved. The separate transformer is adding cost just to get a working tap changer. It was noted 100 taps can be built and technology is more or less available. He clarified that existing designs tend to be based on a fully mechanical solution but power electronic solutions are possible.

24. HM informed the group a tap changer with a complex tapping arrangement will not be possible with nuclear power plant as they have to use proven technology and more modern solutions are not proven. He noted the nuclear industry are not allowed to use a fully computerised system but need to have a backup system that can be manually operated.

25. PB asked a question about the time taken to reach the desired tap level. The group had a discussion on the different tap change times. KK highlighted that the aluminium industry has transformers with 100 taps. PB said in terms of generators, it may take several minutes to go through 50 taps. GS asked about the losses on the system and PB replied that new transformers don't have many losses.

26. KK highlighted that with distribution transformers on the Belgian system, the first tap change takes 30 seconds and the subsequent tap changes can be completed more quickly. The generator step-up transformers have no tap changers.

27. PN raised a question about the maximum tap change level to the group. LS replied that they have been able to change 100MVAr in one go by using a combination of different transformers. AJ explained that according to the generator compliance team the tap changing time should be between 30 seconds to 1 minute. PB raised concern that it would be challenging to design a transformer with 100 taps and which could tap within 30 seconds – 1 minute.

### Option 2A

28. AJ explained the difference between the variants of Option 2 (Option 2A and Option 2B).

29. BA delivered a presentation on option 2A and explained that in this option the majority of the reactive power change would be achieved through tap changes on the transformer. He added

that the Generator terminal voltage level for this option should not be less than 1.0pu but could be up to 1.03pu based on the previous information received to date. BA explained that the number of taps required would depend on the reactive range and also the short circuit level at the Connection Point.

30. PN questioned the prescriptive terminal voltage ranges. Option 2A suggests that the generator can only operate between 1pu to 1.03pu. AJ explained that terminal voltages below 1.0 pu were not desirable due to the reduction in stability margins. PN replied that there is no reason to have the prescriptive range between 1pu to 1.03pu and if NGET want this prescriptive level then there should be some justification behind it.

31. HM agreed with PN about the prescriptive ranges. HM said that the ranges for reactive power and stability requirements should be the responsibility of the designer. HM suggested that the requirements should be specified in terms of functionality rather than the detailed operation.

32. KK raised a question about justification of the 1pu limit. PB highlighted that due to the difference in the commercial drivers and the history behind the British Grid System, onload tap changers rather than variations in Generator terminal voltage had traditionally been used.

33. AJ explained, based on studies completed by BA and HM, that there was deterioration in system dynamic performance with the terminal voltage reduced below 1pu.

34. GS said that it was his view that the workgroup was happy with allowing varying terminal voltage if this addressed the need for an excessive number of taps. Working through the legal text would allow the group to discuss the different clauses for reactive and stability requirements.

**Option 2B**

35. BA explained the work involved behind option 2B. BA explained how this option would reduce the need for more taps as the reactive power requirement can be controlled by a coarse tap with the fine control being achieved by varying the Generator terminal voltage . BA added that an AVR with good resolution allows achieving MVAr instructions and HV busbar voltage with a much better accuracy through adjusting the MVAr output. BA also added that this option would require NGET to do further work with regards to changing the load flow algorithms, but NGET would not discount this option if chosen and will do the further evaluation work.

    **Action: NGET to investigate implications on load flow algorithms**

36. KK questioned the load flow algorithms and how they are used by NGET. AJ explained that the NGET (ie the modeller) sets the target voltage at each HV Generator Connection Point and the algorithm calculates the MVAr requirement and operating point. PN suggested that NGET should only look for how many MVArs are required at the Connection Point and not worry about how it is achieved.

37. The group discussed how the required MVAr level could be achieved in option 2B. HM explained that the clause should not require taps that will never be used and clarified that the last transformer tap might be impractical to achieve. HM requested that this should be taken into account when phrasing the legal text.

38. PB explained how the different options were created. NGET started to only look at tap changers first and then use terminal voltage control at the maximum/minimum taps. This later evolved into using tap control for coarse MVAr steps and terminal voltage control for fine tuning the output between these MVAr steps. PB added that varying terminal voltage achieves precision while large tap steps ensure that the entire reactive capability range is covered.

39. PB said using terminal voltage for precision, increases the step change in MVAr allowed for a tap action. PB highlighted as long as the reactive power requirement of the Grid Code is met then Option 2B is the preferred option. LS was in agreement with PB on option 2B.

40. HM explained to the group how he conducted the study along with NGET. He explained that he had established the variation in critical fault clearing times over a range of short circuit levels with the generator running at various points on the operating chart.

41. KK referred to the fault ride through requirement that Generators need to meet with fault clearance times specified in the Bilateral Agreements. KK didn't agree with voltage level to be limited to vary between 1pu and 1.03pu 'as long as the generator can meet the Grid Code stability requirements and HV voltage/reactive power control requirements.

42. GS highlighted NGET were comfortable in principle to allow terminal voltage to be dropped below 1pu but that this would have a knock on effect in other areas. For example, an assumption would have to be made about what terminal voltage to consider when assessing the fault ride through capability and stability of a generator. AJ also added that if Generator terminal voltage was reduced it could make the excitation performance requirements more onerous for the generator.

**Option 3**

43. AJ explained that option 3 was ruled out in the last workgroup meeting as it reduces the reactive reserves available

44. BA presented a slide on the +/- 25 MVAr tolerance. He highlighted that National Grid currently operates to the nearest 1kV and with the removal of the MVAr tolerance level the voltage step change (based on the studies conducted) allows 4kV steps.

45. BA highlighted that with option 2B the step change can be exceeded past +/-25 MVAr range but the precision is achieved through varying generator terminal voltage control.

## RfG Requirements

46. AJ highlighted that the outcome of this workgroup should not be in conflict with the RfG requirements. JN asked whether the discussion that the group had was in accordance with RfG or not. AJ confirmed that the current workgroup had considered the RfG requirements which had been included in the slide pack.

## Preferred option

47. AJ highlighted that NGET have been working on a draft workgroup report which explained all the options in detail. He added that all the discussions and modelling work had been included in the report. PN questioned why NGET prefers option 2B over option 2A. AJ explained the main differences between both options. PB added that in option 2B the taps can be more fine-tuned with wide terminal voltage variations. It also needs a fewer number of taps and is easier to specify.

48. JN highlighted that selecting option 2B could cause issues to the normal operation of the generator as it involved both tap change and varying terminal voltage. JN said that option 2B should really only be applied to very large generators with wide tap ranges.

49. HM explained that that if the current reactive range requirement (0.85pu lagging to 0.95pu leading at the generating unit terminals and a voltage range at the Grid Entry Point ranging from 0.95pu to 1.05pu), then generators would require an on-load tap changer since such a range could not be achieved with terminal voltage variation only. JN highlighted that the existing plants will have to carry on operating the same way.

50. JN highlighted that with two operations in Option 2B there would be more implications for Generator control staff. The existing requirements allow NGET to give the instructions to the generator and the generator will automatically vary its MVAr output. If Option 2B is selected, it

would require NGET to monitor both the tap change position and the terminal voltage variation.

51. The group had a discussion on the advantages and disadvantages of option 2B. Concern was raised on what the difference was between the HV voltage variation and generator voltage variation.

## Discussion

52. The group had a discussion on the proposed legal text for the workgroup report. Discussion centred around whether legal text should be prepared for one option or more options. The group was in agreement that there was no need to develop legal text for all the options and the consensus was that only Option 2 B should be developed.

**Action: AJ / BA to prepare draft workgroup report**

53. The legal text had reference to Rated terminal voltage – JN highlighted that Rated MW should be the correct term and not rated terminal voltage. JN added that the terminal voltage is not set by the manufacturer but it is set by the Generator. HM highlighted that even if the Grid Code doesn't have any reference to the terminal voltage or 1pu there should be some background reference available in the compliance process.

54. LS highlighted that the 1pu name plating is not set by the generator but by the manufacturer. LS added that the generator may operate the Generator at a value greater than 1.p.u.

55. PB highlighted that NGET should not mandate the rated terminal voltage but the Generators should tell NGET what it is. AJ highlighted that the changes made to the legal text for CC.6.3.4 would also require changes to BC2.

56. PB highlighted the point about terminal voltage ranges to be set between 1pu and 1.03pu in CC6.3.8(a). It was noted that the value should be 1.0p.u or above with no upper threshold as this value should be specified by the Generator.

**Action: AJ to review and develop revised legal text**

**Action: AJ to consider inclusion of an explanatory note within the Guidance Notes for Generators document and discuss this issue with the Generator Compliance team.**

## Next Steps

57. The group highlighted concerns with the legal text and suggested changes.

**Action: AJ to review the legal text and incorporate the suggestions**

58. The workgroup members were in agreement that the workgroup report should be presented to the March 2015 GCRP and that they need to review the report two weeks in advance..

**Action: AJ / BA to tweak the workgroup report and send it out to work group members by week commencing 19th January.**

59. The next workgroup meeting was confirmed for the 19th February 2015.

**Action: Workgroup to review the workgroup report and comment back by the 4th March so changes can be incorporated before next GCRP on 18th March 2015.**

## AOB

None