Minutes

Meeting name	GC0075 Hybrid Static Compensators
Meeting number	3
Date of meeting	22/10/14
Time	10:00-15:00
Location	Holiday Inn Birmingham Airport, Coventry Road, B26 3QW

Name	Initials	Company
Antony Johnson	AJ	National Grid, Chair
Richard Ierna	RI	National Grid
Franklin Rodrick	FR	National Grid, Technical Secretary
Catherine Hiorns	CH	National Grid
Charles Cresswell	CC	Senvion UK
Rui Rui	RR	Iberdrola
Isaac Gutierrz	IG	Scottish Power
John Diaz de Leon	JDL	American Superconductor Europe
Razvan Pabat-Stroe	RPS	Scottish Power
Lee Holdsworth	LH	RES
Laurent Poutrain	LP	VIZIMAX Inc.
Philippe Maibach	PM	ABB
Simon Vogelsanger	SV	ABB
Sigrid Bolik	SB	Senvion UK
Mick Barlow	MB	S&C Electric
Steve Mortimer	SM	S&C Electric
Clifton Ellis	CE	S&C Electric
Alireza Mousavi	AM	ABB

Apologies

Name	Initials	Company
Graham Stein	GS	National Grid
Sridhar Sahukari	SS	DONG Energy
Mick Chowns	MC	RWE
Mike Lee	ML	Transmission Investment
Peter Jones	PJ	ABB
Peter Thomas	PT	Nordex
Shafiu Ahmed	SA	Siemens
Narend Reddy	NR	American Superconductor Europe
Damian Jackman	DJ	SSE Generation
Ian Cunningham	IC	Alstom Grid
Dave Walker	DW	Alstom Grid
Fahd Hashiesh	FH	ABB

1 Introductions/Apologies for Absence

1. AJ started the meeting with a brief introduction of the aims of the workgroup. . He highlighted the purpose of the meeting was to pick up the actions from the previous meeting and find a way forward. The working group members then introduced themselves.

2 Minutes from previous meeting

2. The previous workgroup meeting minutes were discussed; there were no further comments or amendments. The workgroup confirmed that the previous minutes were a true and accurate reflection of the previous meeting.

3. The actions from the previous meeting were reviewed; all the actions were addressed in the Hybrid Statcom/ SVC - Update Presentation.

3 Hybrid Statcom/SVC – Update – Presentation

4. RI delivered a presentation providing a progress update on the National Grid actions from the previous meeting.

5. RI advised that National Grid's Technical Specification (TS.2.11) outlines the requirements for SVCs connected to National Grid's Transmission System. RI covered the three main capability requirements of SVC's operating under fault conditions, these being or voltages between min cont. and 0.8pu for $\leq$20s, for voltage between 0.8 to 0.4pu for $\leq$1.5s, For voltages below 0.4pu for $\leq$0.5s. RI reminded the group that Hybrid STATCOM's/SVC's working to this specification would not be allowed to switch out their capacitors on short circuit unless the voltage depression was sufficiently long enough and deep enough that the above were exceeded.

6. RPS action to provide information on further tripping events and voltage depressions was assessed. RPS advised that data on voltage depressions would be unhelpful, as it would be dependent on the system configuration at the time of the event. RPS carried on presenting a spreadsheet with different faults on different systems (meeting notes captured in the Discussion Section). CC advised that data from wind turbines that correlates with the fault events was unavailable.

7. RI talked about the DAR time, Reclaim times and the voltage fluctuation requirements for National Grid, Scottish Power and SHE Transmission. AJ gave clarification on voltage fluctuations and highlighted that a lightning strike is not the same as a voltage fluctuation. RPS advised that the worst case scenario would be a double circuit fault with graded reclaim times. He advised there may be cases where there could be3 trips in 20 seconds.SB queried what type of oscillations would occur post fault, whether these would be damped or not. MB noted this would be critical to understand for Hybrid Statcom designs. AJ noted that this would be fault dependant (i.e. dependent upon the type of fault and location within the system), but would be picked up later in discussion in establishing the best way to identify and test requirements on hybrid Statcoms.

8. RI explained the analysis of the Scottish storm data. RI explained the time taken by the Statcom to be ready to respond after an event. RI highlighted that the Scottish data was recorded to the second but NG data was only recorded at one minute intervals which skews the overall result. RI advised that the Blue line on the graph was an average time taken by all the events.

9. RI also noted any events that occurred at the same time (or less than 1 second apart) in the Scottish Storm were treated as the same event. This reduced the severity of the test case event scenario.

10. RI discussed Hybrid SVC's currently in service and available in other European countries which consist of a mechanically switched shunt capacitor & shunt reactor in combination with an SVC.

It was noted that the main constraint on repeatability is the Spring Recharge Time for devices currently in service, which only allows 3 – 4 operations per minute. RI highlighted that there can be an estimated 20% in saving between a fully controlled electronic SVC and a Hybrid SVC. In addition, from National Grid's figures an SVC is believed to be 12 – 50% cheaper than a STATCOM.

11. RI briefly mentioned the Fast Hybrids available from European manufacturers. It was noted that this equipment is compliant with the Grid Code of meeting the initial 1 second response time. RI highlighted that the Repeat Capability depends on the switch type fitted and is frequently determined by the spring recharge time. It was noted that with appropriate switches much faster times are possible and 1 second has been discussed. RI advised that at the time the slides were created there was no costing information available but since then the manufacturer in question has stated the anticipated installed costs to be 20% less than a non-hybrid STATCOM solution.

12. RI discussed a High Speed Transformer Switching application on a GB Wind Farm which used similar switch controller technology as there are devices in the same range for capacitor and reactor switching. RI highlighted that the only limitation on these switches was the Thermal capability of the driver unit which currently limited the switch to once a second 10 times consecutively. The issue of rapid switching and implications of Trapped Charge was also discussed.

13. JDL noted that whilst high speed switches may be able to operate quickly, he believed there would need to be a mechanism to disperse the trapped charge within the capacitors. JDL felt this was normally the limitation on switching times and not the switches themselves. JDL further noted that whilst thyristors could be used in these applications without switching perfectly on the zero crossing point of the wave form, it would have significant problems with trapped charge within the capacitors.

14. CE and LH noted and believed such designs did exist. However these must be designed into the device. LH noted it would be possible to use a contactor rather than a circuit breaker, in which case there wouldn't be a need to remove the trapped charge, but a requirement to endure an internal arc for 3 or 4 cycles. The key to this being the device being purposefully designed to switch rather than breaking fault current. LP agreed this could be achieved with some technologies, by using phase angle to predict break point and avoid restrikes.

15. RI stated the RfG requires that 90% of the change in reactive power must be delivered within t1 (1-5 seconds). The t1 time period will vary between countries as it is set by the TSO. Similarly, the t2 time period is set by the TSO within a range of 5 – 60 seconds.

16. SB noted she did not believe RfG was looking for repeatability but needed to meet these requirements for voltage step change.

17. RI talked about the interpretation of the RfG. RI explained that the RfG states that the Power Park Module should have a steady-state reactive tolerance no greater than 5% of the maximum Reactive Power. RI added that this requirement is essentially the same as the GB Grid Code.

18. PM queried the phrase 'Statcom can produce current during faults' and ask for greater clarification on what types of faults were to be considered, balanced or unbalanced faults. AJ noted that CC.6.3.15 of the Grid Code currently requires 'maximum reactive current to be provided during a fault', but RfG was much stricter on this point. RSP noted the majority of 3phase balanced faults were caused by Earth Switches not being removed after maintenance, this therefore would lock out at the point of DAR. RSP therefore felt repeatability of three phase faults was unnecessary and attention should be focused on single-phase to ground faults, which account for 90% of all faults.

3 Test Network – Presentation

19. SM delivered a presentation on the performance of different STATCOMS within a defined test network.

SM advised that a typical 54MVAr Statcom was modelled with a high overload capability and under this scenario it is possible to use a reduced rating of the inverters to achieve the same critical clearing time. This study was used as a base case with the next two Statcoms purposefully sized to provide similar critical clearing times.

20. SM talked about the performance of a Hybrid DStatcom under fault conditions and the response observed when subject to Critical Clearance Times.

21. SM explained the Critical Clearance Times for different types of STATCOMS. MB talked about Scottish Storm events that occurred within 2 minutes and 39 seconds of each other which were assumed to be close to the SVC locations. MB explained the scenario of having one 3 phase fault followed by four single phase faults and what the maximum reactive power output would be from a Statcom.

22. MB referred to slide 5 of the presentation and explained that if there is one 3 phase fault followed by four single phase faults, then the MSC / MSR doesn't need to switch in and out. It was noted that if there is another 3 phase fault then the MSC requires additional switching capability.

23. LH asked about the repeatability of the Hybrid DStatcom and MB answered that it takes 10 seconds before it is possible to reuse the overload capability. In this scenario the MSCs would need to be capable of switching. MB stated that he felt that it was excessive to expect reactive support for multiple 3 phase events.

24. Several members of the workgroup supported MB's opinion that the ability to support multiple three phase events would be too expensive compared to the additional benefits it would bring.

25. MB stated that the equipment should be defined and should not be too prescriptive. RI supported this view, agreeing NGET did not want to exclude technology or new designs; however there are challenges on how to phrase this within the Grid Code in an appropriately clear way which captures the need to be ready for repeated events. IG noted in some designs he would expect the turbine to do the majority of the work and the Grid Code requirement needs to reflect the range of solutions available.

26. CE highlighted concerns over the unavailability of technical requirements for hybrid technology in the Grid Code. AJ added that the Grid Code is technology independent. MB added that the only way to check compliance of equipment under fault conditions is through running simulations.

27. MB further noted the repeatability requirement would not be tested by the compliance team as National Grid would not want to apply any form of live fault ride through tests yet alone several repeated fault events. Therefore compliance can only be proved through simulation. Clarity on this within the Grid Code and the compliance team would be appreciated.

28. RPS questioned the switching of the first or the second MSC in case of a second three phase fault. MB gave an explanation of the switching of the MSC's.

29. CC highlighted concerns over unclear interpretation around repeatability in the RfG. It was noted that more information on the number of events will be required before presenting an update to the GCRP panel in January 2015. CC felt a need to clearly justify why repeatability is required and not just use of the RfG requirements as these were open to interpretations.

30. MB questioned the issue of voltage depressions and highlighted that there should be clarity between steady state and fault ride through and the reactive power response requirements in each instance. CC noted that this would be very dependent on the individual droop and maximum and minimum reactive power specifications. It was noted – depending on how these are selected there may be little difference in the response of a hybrid Statcom to a voltage depression or a step change. The use of a large droop characteristic and a small change in voltage magnitude would result in the hybrid Statcom responding to the maximum of the devices' limit. CC instead believed the requirements should focus on the repeatability of events.

31. MB suggested that NG should clearly define credible faults so the manufacturers can produce compliant equipment. RI proposed using the example data from SP to establish a proposed

requirement, for example 5 events in two minutes or 4 events in one minute. This could be used as a starting point to establish what would be reasonable.

32. RPS highlighted that there can be more than one 3 phase fault within seconds and that more work needs to be done to define the events. RPS stated there was a need to model the impact and the effect of the equipment not being available after several events. RSP also noted he would suggest 3 events in a minute as an absolute minimum, RSP felt this occurs several times a year on some circuits.

33. RI highlighted that there is a lot of synchronous generation connected to the System at the present time but going forward from 2014 there will be a lot more asynchronous generation including windfarms. The transmission system will be more reliant on reactive compensation from asynchronous plant this makes it important to install equipment with the appropriate response. MB highlighted that the idea of RfG is to enable cross border trade and that the UK should not be made more expensive that the rest of EU. RSP noted the GB network had very different issues to continental Europe and therefore may need additional requirements to ensure a stable network is maintained.

34. **ACTION: AJ and RI to produce a view on what would be a reasonable number of repeatable events.**

35. RI noted they would look at what would be credible to secure against for establishing a worse case. The current scenario considered occurs approximately once a year. RPS suggested considering analysing more than 1 storm event over a few years to define the events. The workgroup meeting discussion is only based on 1 Scottish storm event.

36. MB noted that any proposed requirements should only cover credible scenarios, for example in severe storms with high wind conditions there would be no output from the power park module anyway, as the wind farm will cut out. SM noted in the Grid Code Connection Conditions that Generators should be able to withstand onerous conditions, not the worst case conditions. AJ agreed, highlighting that the SQSS requires compliance with repeatability and it should be based on a cost benefit analysis.

4 Discussion and Next Steps

37. AJ noted that any new requirement introduced into the Grid Code would not be expected to apply retrospectively. It was noted that when developing the legal text, an effective date from which the requirement would be expected to apply would be included within the drafting.

38. DJ suggested that the manufacturers should be given different event scenarios so they can calculate the cost of any extra capability. For example, by using RI's graph, picking several different points on this curve and asking for indicative costs to meet this. This would aid the workgroup in defining the additional cost of the requirements and therefore a cost benefit analysis.SB supported this view, noting she did not believe the workgroup currently had a large enough focus on the cost of meeting the requirements. RI added that the Hybrid Statcom questionnaire is intended for this purpose.

Scottish Power Presentation

39. RPS presented examples of different trips on the Scottish Network. The presentation highlighted the different circuits involved, cause of the trip, faulted phase, distance from the fault and the fault clearance times.

40. RPS presented an example for the Hunterston – Kilmarnock fault (400kV). RPS explained that the cause of the fault was lightening on the Yellow phase. The distance of the fault from Hunterston substation was 7.65km and from Kilmarnock substation was 61.4km. RPS added that the voltage retained at the Hunterston end was 42.7kV and at Kilmarnock was 96.3kV. The time taken to clear the fault at Hunterston was 91.8ms and at Kilmarnock was 102.8ms.

41. RPS presented another example for the Cockenzie - Eccles fault (400kV). RPS explained that the cause of the fault was a fallen tree that caused a fault on the Red phase. In this particular example RPS highlighted that a higher retained voltage was observed – 143.3kV Cockenzie end

and 195.5kV at the Eccles end. The fault clearance times were higher than the previous example – 959ms at Cockenzie and 918ms at Eccles.

42. MB noted that using these examples, the duty on the wind farm would not be particularly onerous. RSP noted it depends where in the system these faults are in comparison to where the wind farms are located and that he had picked particular examples to gain a range of different fault types but not necessarily the most onerous example.

ABB Presentation

43. AM returned to the concerns about the repeatability requirement of the hybrid Statcom. He noted there is a need to consider the internal mechanisms of the Circuit breaker and the trapped charge issues together.

44. AM described the operation of a circuit breaker and noted the use of a mechanical latch mechanism would still require an extinguishing medium for the arc. For example for SF_6; the arc is extinguished close to the zero crossing point if it's cold and this arc would last typically up to 1.5 cycles in the circuit breaker before it is extinguished. To do this repeatedly in a short period of time would result in additional degradation of the circuit breaker, which would have not had an opportunity to remove waste particulates from the breaker mechanism, this would also increases the risk of a restrike.

45. AM highlighted that according to IEC standards, circuit breakers are not tested for 360 events in an hour (assuming the requirement to be able to respond to multiple events within a minute) and there should be a defined current and voltage type test. This also applies for the vacuum breaker, although used at lower voltages, it is not tested for that many operations within an hour and therefore there would be a need to increase the maintenance frequency to understand the impact on the equipment. AM further noted that whilst a solid state breaker, using thyristors with forced commutation may be possible, it has not previously been applied.

46. RI added that the purpose of the questionnaire was to find out what was realistic and what the cost implication will be. RI proposed to include different timings, to explain the requirements over different specific time frames. For example we might request if 3 operations with 1 minute would be possible and/or 5 operations within an hour etc.

Vizimax Presentation

47. LP delivered a presentation on the different types of equipment and how they can be used in a situation of a fault on the system. LP explained the operation of the circuit breaker and a shunt reactor.

48. LP highlighted IEC 62 271-302 is used for circuit breakers only and considers simultaneous events. When using circuit breakers to switch compensation equipment it must ensure that the current is interrupted properly. There is a need to ensure the design avoids the risk of re-ignition or surges, particularly with compensation equipment as this can result in high frequency disturbances.

49. LP noted the circuit breaker needs to mechanically open to ensure there is enough leverage to break the current. Then the maximum dielectric withstand strength must be able to dissipate the energy without breaking down electrically, until the zero crossing point is reached to allow the arch to be extinguished. If this is done correctly, there is no damage to the equipment or disturbance to the system. The circuit breaker has been specifically designed to satisfy this requirement, but too much energy dissipation will lead to equipment damage and increases the risk of a restrike.

50. LP also highlighted the number of operations a circuit breaker is expected to undertake which is dependent on the mechanical wear. For example, air blast is limited to very few operations within a short space of time as the mechanical wear is significant. On the other hand a vacuum or electromagnetic designed circuit breaker used for the implementation of SVC technologies specifically designed for switching capacitor banks and shunt reactors can perform many more operations. LP advised that 2 operations could be performed within a 10-20 second time frame. LP explained that the reason for the reduced mechanical wear is due to the dielectric that has

reduced rate of decrease of dielectric strength (RDDS) and therefore can withstand more operations within a shorter time period.

51. AM agreed that the number of operations is very important for the design. For example, with 1 operation per minute there would be a need to utilise point on wave switching technology. There would also be a need to understand the opening time for the capacitor bank and whether the system is on the positive or negative part of the wave form. This is particularly important as the capacitors have not discharged as they would need to accommodate the extra energy change. There is currently no solution designed to switch using the point on wave and capacitor discharge solution.

52. LP supported AM's view noting that when switching with breakers it was important to consider the trapped charge. It is possible to fast switch the capacitor bank, to provide repeatability in a short space of time, but there is a need to consider the residual charge issue. One of the ways this is achieved is to dynamically adjust the phase angle and he demonstrated how this has been done in his presentation.

53. AM highlighted that there is a bottleneck in the dissipation of trapped charge from the capacitors and not the circuit breaker. LP highlighted that should high numbers of consecutive operations be mandatory – the need for the mentioned figure of 360 operations/hours being very unlikely - circuit breakers with electromagnetic actuators could be considered, and such devices are to be found in medium voltage portfolios at leading manufacturers (in most cases combined with vacuum type switching components). AM further highlighted in these situations the transformer may then be the bottleneck for the reactive support requirements, but this must ensure the requirements accommodate the most appropriate solution for individual connections.

54. AM said that if the number of events per minute can be defined then the manufacturers can run simulations and provide the results. RI added it would be possible to use a performance degradation curve (as that in the slides) to establish reduced reactive power support in the event of many repeated events, with the exact number to still be defined.

55. ACTION: RI and AJ to go through more data and establish an appropriate sequence of faults that can be used as a requirement on repeatability.

56. LP noted there is a limit to what can be expected from a circuit breaker, the limitation is in the range of approximately 40kV. LP noted that Statcoms are usually less than 40kV, and that fast switching solutions are possible, and proven in SVC capacitor bank switching designs.

57. LP noted there is the option to look at different solutions, for example super-fast single pole operation. LP further noted that in most cases either fast switches and not circuit breakers, or switches behind circuit breakers could possibly be used.

58. AM further highlighted concerns about the number of proposed switching operations. Considering a wind farm reactive power support having approximately 10 operations within 12 minutes, adds up to lots of switching operations. If there is a need to be able to support 360 operations within 1 hour, this needs to be established. Most circuit breakers have a lifetime between 200 and 5000 operations.

59. MB agreed, noting that this could result in changing lots of circuit breakers every year. Further to this, the repeatability criteria of every minute, (irrespective of fault type) would force everyone to install solid state devices.

60. RI noted that these are relatively infrequent events and would not be required to operate many times within a year. RSP noted that the term Infrequent was a defined term in the SQSS.

61. ACTION: RI to establish the likelihood of this type of event occurring in the same area more than once a year

62. ACTION: LP to circulate the slides

63. ACTION: RPS / RI / AJ to come up with a criteria (e.g. 4 events repeatable per minute) to be presented at the next meeting.

64. MB further noted the need to be able to comply with something measurable. He noted the situation at the moment is that the Grid Code is open to interpretation so problems are not generally identified until the compliance phase. It was noted that during compliance testing different people have a different understanding of the same sections of text.

65. RI noted that it is unlikely if a formal repeatability test would be carried out whilst on site. He did however advise that a manufacturer's validation and a statement of compliance would be required.

66. RI said we can establish from the data, the number of events per minute and also the timelines so that the equipment can be monitored under real system events. CC added that the number of events per minute should be clearly defined.

67. MB questioned what is considered as a credible fault. AJ answered that it's based on the SQSS. The SQSS covers approximately 99% of incidents, but not all; otherwise you would need to design a gold plated transmission system for a minor increase in System reliability.

68. PM asked if a full suite of events can be provided to the manufacturers so that they can run simulations. DJ questioned if it was possible to provide a range of values which will allow the manufacturers to look for different criteria and also look at the cost benefit analysis.

69. MB suggested it would be useful to develop some draft legal text on the repeatability criteria required. This would then be circulated to workgroup members in advance of the next meeting.

70. DJ suggested putting forward several criteria allowing manufacturers to indicate the cost which was likely to apply to them. RI agreed, suggesting several criteria and then these can become a negotiating position for the rest of the workgroup. RI further suggested a simple specification and then this can be talked around.

71. MB proposed that the initial communications on this should be completed via email to ensure as much preparation work as possible had been completed prior to the next meeting.

72. ACTION: NGET to develop draft legal text to specify the performance and repeatability requirements.

5 Any Other Business

73. NA

6 Date and Time of Next meeting

74. The date and time of the next meeting is to be confirmed subject to a doodle poll clarifying availability. It is anticipated this will be at the end of November or the beginning of December. Post Meeting note: - Due to general availability and scope of work it is proposed that this is now scheduled for early January.