Reply to the Chat questions GC0137 Workgroup meeting 2 – Issue 001

Replies to the Chat data

The replies to each Chat question are given in the Red text.

The **Section** numbers refer to the **Sections** in the companion document "Enstore's guide for GB Grid Forming Converters – V001" issued by Enstore. There are also cross references to "Enstore**'s** notes for GB Grid Forming Converters – 004" that was previously circulated and copies are available via an email request.

0. from BM76057 to everyone: 10:08 AM

No issues with that- agree has been discussed previously

1. from BM76057 to everyone: 10:25 AM

Two important points- Synchronous machines respond to this repetitively, they inherently do so, both for small and large disturbances, power electronics devices would similarly need to be mindful that the response would be inherent to the control and as such the power electronic response needs to be capable of repetitive response of variable extent.

This is defined in **Section 1.2**

2. from BM76057 to everyone: 10:26 AM

Also (second point) synchronous machines will act to damp unbalanced as well as balanced disturbance via damper winding. again, Power electronics devices would need to consider how this is replicated.

This is defined in **Section 1.3 and Note 1.**

3. from ifte huq to everyone: 10:28 AM

So, is the understanding correct that the Grid Forming behavior is expected always with an energy storage?

Yes, unless it is the VSM0H variant that does not have software inertia. Note that VSM0H also provides a benefit to the System at a local level in terms of contributing to fault infeed, minimizing vector shift and maintaining an improved voltage profile during system disturbances. As such, both VSM and VSM0H have benefits to the system and should enable an optimized cost solution to be developed to secure the system.

4. from Sigrid.Bolik to everyone: 10:28 AM

I think we should discuss as wind turbines do have a rotating element, which could be used as inertia in the same way.

This is defined in **Section 1.5.**

5. from BM76057 to everyone: 10:29 AM

Ifte- I don't think it's essential- the effect of stored power could come from de-loading the energy source from its maximum power output as long as the above philosophies are respected when it is doing so.

This is allowed provided the energy source can reliably supply the required levels of power and energy for importing and exporting Phase based Inertia power at the required rate of change and as declared by the Generator or HVDC System Owner in accordance with Table 1.0 and 2.0 of the Grid Code specification.

When this method is used it must be in use for an agreed period with a corresponding reduction of the payments for the reduced steady output power. This approach would be particularly attractive at low demand periods, with a surplus of generation. It is noted that Power System Stability margins are lower under these conditions especially when the reactive gain is quite high.

6. from Gert Karmisholt to everyone: 10:29 AM

like to discuss what the marked is for H0 GF converters

I think you mean the market for VSM0H converters. As noted, VSM0H does have a place in the GBGFC Market. The market arrangements are outside the scope of this workgroup but the Generator should declare their capability through Table 2.0 of the Grid Code specification. Based on the price of the service NGESO will establish the volume of GB Grid Forming required, less the contribution from the basic plant schedule, the stability pathfinder work and the surplus to be procured through the Grid Forming market.

We unfortunately do not have figures at present on the size of the GB Grid Forming Market but we expect these will be published in the fullness of time through the stability pathfinder work which is available from the following link.

https://www.nationalgrideso.com/research-publications/system-operability-framework-sof

A combination of full GBGFC and VSM0H will be used to secure the system. As it is expected that VSM0H will have a lower cost that a full GBGFC it is expected that this will produce an attractive solution to both participants and NGESO.

7. from Andrew Roscoe to everyone: 10:30 AM

I have been having debates with Eric and Antony and I would argue that VSM0H should not be excluded from the "suitable" list. More on this later!

Agree – this has been clarified in **Section 1.10** and other associated sections.

8. from Sigrid.Bolik to everyone: 10:30 AM

0H stands for the 0 Inertia constant

Agreed

9. from Sridhar Sahukari to everyone: 10:31 AM

How is bandwidth of control system defined?

This is defined in **Section 1.8.**

10. from Andrew Roscoe to everyone: 10:31 AM

I think we will get to this later!

Agreed

11. from BM76057 to everyone: 10:32 AM

not sure I concur that VSM-0H has limited inertia- its response is corrected within a cycle- so I don't think could be defined as an active power inertial response. or a practical angle support. voltage support perhaps.

This is covered in **Section 1.10.**

12. from Andrew Roscoe to everyone: 10:38 AM

I think every manufacturer may have their own diagrams, not necessarily exactly matching those presented here.

This is covered in **Section 0.**

13. from Thorsten Buelo to everyone: 10:38 AM

The equivalent Circuit model of GBGFC (slides 16/17) may be one approach to provide the functions required or better - the behavior of a synchronous machine. It's useful to understand the requirements, but it shouldn't be a prescription of the implementation or the basis for plant-internal key parameters of the plant. Can you please clarify the role of the equivalent circuit within the requirements?

This is covered in **Sections 1.2, 1.6, 1.8 and 1.11**

14. from Ben Hillman to everyone: 10:39 AM

In relation to Ben's points above, at what points are the converters required to maintain GFC mode, and what kind of behavior they will exhibit if a fault occurs? I.e. If current clipping or similar occurs, what kind of currents/voltages are expected to be produced? For unbalanced faults could the behavior change throughout the fault period.

This is covered in **Sections 1.3 and 1.4.**

15. from Sridhar Sahukari to everyone: 10:40 AM

How is the value of the damping factor determined?

This is covered in **Section 1.6 and 1.11.**

16. from Martin Aten to everyone: 10:42 AM

Gain Margin and Phase Margin are defined from an Open Loop Bode Plot, not a Closed Loop Bode plot

Agreed but these cannot be extracted from a NFP plot. At this stage, it is the intention of NGESO to provide a best practice / guidance note on this issue which would be a separate document (published on the National Grid Website) rather than forming part of the Grid Code specification.

17. from Meghdad Fazeli to everyone: 10:44 AM

The Bode plot does not look right. if it was a closed loop plot, the amplitude must be 0 dB for operating frequency!

It would be 0 dB if it was for a closed loop input to output response but it is showing a different response of input power at a varying input frequency so the value at 0 Hz is the Droop gain

18. from Andrew Roscoe to everyone: 10:44 AM

Agree. NFP plot is not intended to (and does not) show "stability". However, it does allow an assessment of several key grid-forming properties.

Agreed

19. from Andrew Roscoe to everyone: 10:46 AM

Meghdad, NFP plot format and interpretation takes a while to get used to … more than can be described here.

A guide to understanding the Damping Factor from a NFP plot will be issued by NGESO for GB Grid forming static power converters.

20. from BM76057 to everyone: 10:46 AM

Hi Sridhar- I would expect the damping factor for a given controller would be connection specific rather than grid code defined- the code would define the expected performance, but different areas of the grid would have different characteristics, so they are expected to influence. worth noting SQSS includes provision for angle stability damping requiring within its definition of stability and stability margin.

This is covered in **Sections 1.6 and 1.11.** As noted poor damping is quoted as a definition in the SQSS this being:

System Instability

i) poor damping - where electromechanical oscillations of generating units are such that the resultant peak deviations in machine rotor angle and/or speed at the end of a 20 second period remain in excess of 15% of the peak deviations at the outset (i.e. the time constant of the slowest mode of oscillation exceeds 12 seconds); or

ii) pole slipping - where one or more transmission connected synchronous generating units lose synchronism with the remainder of the system to which it is connected.

For the purpose of assessing the existence of system instability, a fault outage is taken to include a solid three phase to earth fault (or faults) anywhere on the national electricity transmission system with an appropriate clearance time.

The appropriate clearance time is identified as follows:

i) In NGET's transmission system and on other circuits identified by agreement between the relevant transmission licensees, clearance times consistent with the fault location together with the worst single failure in the main protection system should be used;

ii) elsewhere, clearance times should be consistent with the fault location and appropriate to the actual protection, signalling equipment, trip and interposing relays, and circuit breakers involved in clearing the fault.

21. from Martin Aten to everyone: 10:47 AM

As long as it will be clearly defined what gain and phase margins from an NFP plot represent and what target values are, if it is different from Classical Control Theory.

It is the intention for NGESO to issue a guide to understanding the Damping Factor from a NFP plot

22. from BM76057 to everyone: 10:47 AM

worth discussing further.

This is why a guide to understanding the Damping Factor from a NFP plot will be issued

23. from Sigrid.Bolik to everyone: 10:49 AM

I think it would be worthwhile to use the target values (damping...) within a specification rather than talking Bandwidth

This is covered in **Sections 1.6 and 1.11.**

24. from Duddy to everyone: 10:49 AM

wind turbines have several resonances <5Hz

Data on this is in **Section 3.1** Page 11 of the Enstore**'s** notes for GB Grid Forming Converters – 004.

25. from Sridhar Sahukari to everyone: 10:49 AM

are there any known natural modes between 50Hz to 100Hz?

This is very rare but Power factor correction filter systems have been supplied that have a very low resonant frequency between 50 Hz and 100 Hz. These are C type filters that have very low losses at 50 Hz and high damping to have no significant impedance magnifications in this frequency region. This enables the filter to be switched on line with minimal voltage disturbances other than the change in the reactive current.

26. from Andrew Roscoe to everyone: 10:51 AM

The question here is "what is an essential signal"?

I think you mean external signal but this concept has been removed see Section 1.8

27. from BM76057 to everyone: 10:52 AM

note parallel modification GC0141 ongoing on EMT relevant model provision. To address mine and Ben Hillmans points on repetitive behaviours limiting responses and performance within a non-RMS frame, suitable EMT models will need to be provided. Not suggesting this necessarily needs discussing here but between the two workgroups it will need to be covered off.

Agreed

28. from Meghdad Fazeli to everyone: 10:52 AM

What are the input and output signals for NFP? See Chat 29

29. from Andrew Roscoe to everyone: 10:54 AM

NFP plot is based on grid voltage angle disturbance (frequency/phase) stimulus, and output power is the response. Agreed

30. from Andrzej Adamczyk to everyone: 10:54 AM

Following the example give on slide 28 there is for instance an oscillatory mode related to synchronous generator exciter suggesting that is the exciter control bandwidth is way above 5 Hz. Moreover, it is known from literature that fast exciters are very important for boosting synchronising power, but they are somewhat detrimental to low frequency oscillations. In that context putting a blanket 5 Hz limit on any new device connecting to the grid seems to be a quite blunt measure.

The frequencies shown on the Webinar Slide 28 are the frequencies that must be avoided.

The NFP plot on slide 25 shows that the systems response extends well beyond 5 Hz as it is the inherent Phase based power action that has no bandwidth limits. The peak of the NFP plot is typically in the range of 0.5 to 3 Hz and is the main resonant mode of the system coupled to the grid

For synchronous generators the exciter control needs a high bandwidth to achieve its performance and this complies with the revised bandwidth definitions

The 5 Hz limit is to Control system induced power changes and is in line with the GB Grid code in sections CC/ECC.A.6 and CC/ECC.A.7

31.from Mikek to everyone: 10:54 AM

Is the "Hz/s a proposal for the spec? Or is it already in the G Code?

Data on this is in Appendix C of the Enstore**'s** notes for GB Grid Forming Converters – 004. This data gives the operational limits for the Initial RoCoF and the Average RoCoF and the existing withstand limits.

This data also gives data on a possible increase of the initial RoCoF value to reduce the future Capex implementation cost of Grid inertia.

32. from Mikek to everyone: 10:54 AM

Sorry… 2Hz/s.

See Chat 31

33. from Andrew Roscoe to everyone: 10:54 AM

Whereas "Bandwidth < 5 Hz" appears to be "external input" (stimulus) to output power (response).

This concept has been removed see Section 1.8

34. from Thorsten Buelo to everyone: 10:54 AM

p. 27: instead of providing an equivalent model and parameters, which will be always a compromise: what about providing a detailed simulation model and definition of a set of acceptance tests that show the general capability and behaviour also in conditions at the operation capability limits?

As different suppliers will have their own models it is not possible for NGESO to issue a standard model but NGESO require a standard way of submitting contract data via an NFP plot

35. from Andrew Roscoe to everyone: 10:55 AM

But the question is, what is an "external signal" in many converter-based systems? Some systems may claim to have NONE!

This concept has been removed see Section 1.8

36. from Gert Karmisholt to everyone: 10:56 AM

Grid forming plant: why comply with standard FRT which is PLL based?

A GBGF static power converter must meet the FRT requirements specified in the Grid Code as this is what happens in a real grid system. In other words, if there is a fault on the system, any generator or plant connected to a healthy circuit on the System should remain connected and stable during and after the system fault. Only the equipment connected to the faulty circuit will be permitted to disconnect. If this requirement is not in place it will result in cascade tripping, power loss and eventual blackout.

PLL base control must not be used in Normal system operation and the aim is to avoid PLL operation in Fault modes. See **Section 1.5.**

37. from BM76057 to everyone: 10:56 AM

RoCoF - over what timeframe is this measured? agree with Mike some definition is needed

Data on this is in Appendix C of Enstore**'s** notes for GB Grid Forming Converters – 004. This data gives on RoCoF protection units that operate on a 500 ms RoCoF calculation

It is also desirable to have online monitoring systems that calculate the values of any phase jumps that occur together with the values of RoCoF events. See Section 1.11

Under ECC.6.3.13.2 the ROCOF values are calculated over a rolling 500ms period. Dynamic System Monitoring are required for all Type C and Type D Power Generating Modules and HVDC Systems in accordance with NGTS.3.24.70.

https://www.nationalgrideso.com/document/33196/download

38. from ifte huq to everyone: 10:56 AM

Slide 33: will there be any modification/adaptation of requirements of Fault ride through/iq modulation etc for focusing with Grid forming capability? Because Grid Forming control focuses first on stabilizing the grid so the inertia behaviour or voltage support might be different compared to traditional or current fast fault current injection requirement for example

The provision of the inherent Phase based phase Jump power by a GBGFC is a key Grid Forming feature that was not supplied by existing power converters that aimed to avoid responding to phase jumps. Any plant which has a Grid Forming Capability will inherently be able to supply fast fault current. The revised Grid Code specification (ECC.6.3.19) will include a full requirement on Fast Fault Current Injection.

39.from Sigrid.Bolik to everyone: 10:57 AM

Thorsten, I support a model provision, however, it still needs to be described for persons not directly involved and not having access to the model yet.

As different suppliers will have their own models it is not possible for NGESO to issue a standard model.

If anyone wants more data on modelling GBGFC data can be obtained from academic institutions or consulting companies

40. from Sigrid.Bolik to everyone: 10:58 AM

it was mentioned before that there may be an impact from grid domain and FFCI - the question is, are you exempt, if you bit for the market? FFCI is a core grid code requirement

If you bid into the GBGFC market then the plant design will inherently provide a fast fault current capability, similar to that of a synchronous machine. The updated specification will include this.

41.from Andrzej Adamczyk to everyone: 10:58 AM

Yes, it is quite unclear from the circulated material what is an "external" signal. The block diagram on slide 21 suggest that grid frequency measured at the point of connection is classed as an "external" signal.

This concept has been removed see Section 1.8

42. from Martin Aten to everyone: 11:03 AM

50 degrees phase jump is challenging for a synchronous generator, how could that occur practically?

See Section 1.9

43. from Sridhar Sahukari to everyone: 11:03 AM

how is the phase jump of 10deg or 50deg determined? what could cause that in real world?

See Section 1.9. It is also very easy to detect a phase jump and its value by monitoring software.

44. from Sridhar Sahukari to everyone: 11:04 AM

how is the Grid Entry point considered for Offshore Wind farms with OFTO networks?

If an OFTO connected Offshore Wind farms wants to be compliant with the GBGF specification, there are two issues:

- It is technically possible to add a system at the Interface Point that makes the system GBGF compliant and this is included in Data on this is in **Section 5** of the Enstore's notes for GB Grid Forming Converters – 004. For example, the installation of battery storage as part of a STATCOM installation for example. There is however no issue if the Offshore Generator wished to install GBGFC technology on its offshore generating plant with the requirements satisfied at the Offshore Grid Entry Point.
- The present rules for OFTO networks appear to prevent this from being implemented (as there are issues around OFTO's owning Storage) and this has been raised as an issue that needs to be resolved but this is outside the remit of the Workgroup.

45. from Andrew Roscoe to everyone: 11:05 AM

Lighting strikes and lines opening/reclosing will do that. Many examples.

Agreed.

46.from Sridhar Sahukari to everyone: 11:05 AM

thanks Andrew, 10deg seems practically possible but 50Hz seems too high.

See Section 1.9, but I think you mean degrees

47. from Andrew Roscoe to everyone: 11:05 AM

Again, many manufacturers diagrams will use quite different damping and control schemes

Agreed this is why NGESO cannot issue a definitive diagram and why the existing diagrams are only used to aid illustrative understanding.

48. from BM76057 to everyone: 11:06 AM

Andrew - agreed; angle change of this scale is not unusual- particularly in respect of the timeframes these controls need to respond

Agreed

49. from Andrew Roscoe to everyone: 11:06 AM

Ben M has plenty examples of 20 deg. 50 deg is what's required in DC0037 (if I have that correct) loss-of-mains withstand for vector shift

Agreed

50. from Sridhar Sahukari to everyone: 11:08 AM

thanks Andrew and Ben, good to know.

No comment needed

51.from Andrew Roscoe to everyone: 11:08 AM

50 deg is HARD, by the way!

Agreed

52. from Martin Aten to everyone: 11:08 AM

lightning strikes, and other short circuit events will cause voltage dips, still intrigued what causes the extreme phase jumps. synchronisation relays have been introduced to protect synchronous generators not to be subjected to such extreme phase jumps.

See Section 1.9

53. from Mikek to everyone: 11:11 AM

@Andrew DC0079 (following on from GC0035)

Thank you.

54. from Sigrid.Bolik to everyone: 11:11 AM

I have seen higher than 50 deg phase jumps in faults in South Island of New Zealand (some years ago now), cause by total change of power flow through the network following a fault

Thank you but also see section 1.9

55. from Sigrid.Bolik to everyone: 11:12 AM

don't think it is that realistic in the relatively meshed grid in GB?

See Section 1.9

56.from Thorsten Buelo to everyone: 11:12 AM

so, it's not a 50deg phase shift at constant voltage amplitude, right?

See Section 1.9

57.from Sigrid.Bolik to everyone: 11:13 AM

worth discussing, also for the sensitivity in response

I think that the new issue of the proposed Grid Code will give more data on the phase shift angles for normal and abnormal conditions. See Section 1.9

58. from Sridhar Sahukari to everyone: 11:14 AM

also check if syn. machines maintain synchronism for such phase jumps.

See Chat item 60

59. from BM76057 to everyone: 11:14 AM

Marten, others- a critical aspect of the discussion relates to the timeframe of measurement. RoCoF is generally around 500ms, vector shift can be somewhere in the region 50-60ms; synchronous machines would be responding within 5ms. as the availability of that declines the effect of their damping similarly declines. a GBGFC is responding within 5ms and needs to be resilient to the phase jump it sees- otherwise it trips or limits and by doing so no longer supports in the way required.

I think that vector shift can happen in less than one cycle for certain trip conditions.

A GBGF static converter will have a defined phase jump angle and will have a proportional current response for lower phase jump angles. For larger phase jump angles the current will be the defined current limit value.

60. from Martin Aten to everyone: 11:16 AM

So, question is where exactly the phase jump is, and what the voltage depression at the time. All I know is that if you were to apply a phase jump of 50deg on a conventional synchronous generator, while keeping the voltage magnitude unchanged, the electrical torque stress would significantly reduce lifetime. Hope that doesn't happen at all or rarely in practice.

See Section 1.9

This has been witnessed in Zambia when the main grid supply was lost and a reclosed within one second on to synchronous machines that had not been tripped off the system. The generators had changed speed in the supply off period and then has a large phase transient when the grid was reclosed and many tripped due to a pole slip transient.

This issue is now covered in Enstore's guide.

61. from Sridhar Sahukari to everyone: 11:18 AM

based on the simulations that we have seen so far, only a phase jump without any voltage suppression would translate as voltage dip/rise in the eyes of PLL. but not sure if it's generic enough Hope some of the WTG manufacturers could pitch-in here.

This is why GBGF static converters are not using PLL technology.

It is also possible for phase jumps to give very false frequency changes and RoCoF values with certain monitoring systems, see the initial frequency on slide 14 in the Webinar.

It is possible to implement monitoring systems that do not have this defect.

See Section 1.11

62. from Janet Lees to everyone: 11:20 AM

Do these proposals adequately cover simulation and testing of the short circuit current contribution?

See Section 1.11

63. from Andrew Roscoe to everyone: 11:21 AM

I think there is an expectation that FRT requirement/assessment is roughly the same is it is now.

Agreed

64. from Andrew Roscoe to everyone: 11:21 AM

It's just more of a challenge to be compliant with FRT with a grid-forming device.

Agreed

65. from Duddy to everyone: 11:33 AM

many comments are associated with slides. I suggest those commentators should submit annotated copies of the presentation to ensure their comments are understood in context

This should be done for all future comments.

66. from BM76057 to everyone: 11:55 AM

all- struggle with the concept of no definition of active power response- how is the controller to be tested and verified to physically conforming to GB GFC? perhaps defining the compliance test outcome, with suitable tolerances in lieu of the definition is an option- but not sure what the point of a definition which does not reflect the physical principles of the control is otherwise.

The planned testing will require the validation of a GBGF static converter by using a range of real tests, with defined tolerances, for each of the key performance features.

For example, a defined RoCoF event will be applied and the results recorded

See Section 1.11

67. from Andrew Roscoe to everyone: 2:23 PM

The test on slide 39 implies that for at least 5 seconds your system needs to be able to operate islanded

Agreed but all the test listed are provisional.

68. from Andrew Roscoe to everyone: 2:24 PM

So, the SCR is 0.0

So, for the distribution SCR definition your value is correct

69. from Andrew Roscoe to everyone: 2:26 PM

Comment refers to ECC.6.3.19.4 iv)

That is correct

Modification record

Issue	Date	Details
001	01/11/2020	Initial issue