Grid Forming Webinar Questions and Answers

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Question	Answer
Does minimum short circuit level of zero MVA means Island mode? [Slide 9]	Although being able to operate at a minimum short circuit level of zero MVA comes from the Grid Forming (GFM) capability of establishing a voltage source behind an impedance, there are other considerations for a plant operating in this mode which are beyond the scope of just operating at zero MVA Short Circuit Level and being Grid Forming. We would not expect Grid Forming plant to be able to operate in an islanded mode by default.
Could you explain what the difference is between "inherent behaviour" and a "control response". In inverter-based grid forming resources will implement both via software control algorithms.	It is acknowledged that, for inverter-based grid-forming (GFM) resources, both “inherent behaviour” and “control response” are ultimately implemented through software-based control algorithms. However, the two terms are used to distinguish the nature and timescale of the response, rather than the implementation approach. “Inherent behaviour” refers primarily to the inverter-level response at the instant of, and immediately following, a disturbance. At this very fast timescale, the disturbance evolves so quickly that the internal voltage phasor of the inverter can reasonably be assumed to remain nearly constant. As a result, the observed response can be directly derived from basic physical relationships between voltage, current, and network impedance, and is effectively instantaneous in nature. In contrast, “control response” refers to the subsequent behaviour occurring at a slower time scale, where control loops with lower bandwidth become active. This typically includes outer-loop inverter controls or plant-level controllers, whose actions depend on measured signals and reference tracking. Such responses commonly

	include, but are not limited to, responses driven by changing its power or voltage references.
Synchronous machines have provided stable grids for over 100years. In the last 35 years they have been subject to Grid Codes. With NESO recently adding Grid Forming to the GB Grid Code, a whole raft of new requirements now apply to synchronous machines (GBGF_S). What defects are NESO solving by introducing new GBGF-S requirements which have not been identified in the previous 30 years?	It is acknowledged that the existing Grid Code framework for synchronous machines has operated successfully for many decades and has provided a high level of system stability. The introduction of additional requirements under the Grid Forming (GFM) capability for synchronous machines (GBGF-S) is not intended to address any previously unidentified defects or deficiencies in synchronous machine behaviour. The GFM capability requirements have been introduced to establish a unified set of requirements that can be applied consistently to all potential resources capable of providing grid-forming behaviour, including both synchronous machines and inverter-based resources. It should also be noted that the requirements defined in the Grid Code represent minimum requirements for GFM capability. Additional requirements may be specified through commercial tender processes for particular GFM stability services; however, NESO's service design remain technology-agnostic.
How is NESO planning on incorporating the fact that during large disturbances, such as 60 degree phase angle jump, inverters can reach their hardware current limit momentarily immediately after the event, thus behaving as current source for a short time before other current control limiting functions kick-in? During that time, the power equations of Vgrid x Vinverter x sin(theta)/Xtotal are no longer valid. That would be an interesting nuance to clarify for grid-forming technologies	Within our Grid Code we have performance criteria for plant which has entered the current limitation mode, this is referred to in the Grid Code as the Phase Angle Jump Withstand Limit which is currently 60 degrees. The Grid Code sets two modes of operation for Grid Forming plant, one is a linear operating mode (without current saturation) and other is a non-linear operating mode (with current saturation). When a Phase Change of 60deg occurs, it is expected that the plant would enter the withstand mode (i.e. a non-linear operating mode) in which case the plant current limiting functionalities will be activated. Further explanation on these performance requirements will be included in the upcoming Grid Forming Guidance Notes.

	These effects are being taken into account as part of the ongoing development and modification of the Grid Code. Further clarification is being developed on the expected behaviour of grid-forming technologies under non-linear and current-limited operating modes during large disturbances, including the applicable of modelling assumptions and performance expectations over different time scales. The intent is to ensure that Grid Code requirements remain technically robust and reflect the practical physical limits of grid-forming resources
What should be the explicit environment for the FAT as the current guidance is confusing. GFM FAT is to be accompanied by HIL, does it mean that CHIL is acceptable or a physical hardware of power converter is required. IF physical setup is required (which is PHIL), can NESO clarify what should be the capacity of such setup?	It would be expected that a Control Hardware in the Loop (CHIL) test setup involving physical hardware of power converter controllers in combination with the Power Plant Controller would be used to demonstrate the Grid Forming plant behaviour and also to ensure there are no adverse control interactions during the Factory Acceptance Test (FAT). As per the currently published guidance notes, we would recommend having at least two physical converter controllers used during the FAT. The total capacity of the whole setup is recommended to be scaled up to the total capacity of the plant in specific projects.
Do you also expecting this GF capability as mandating requirement like EU TSO did for IBR in the future? If it is what is the expected date?	NESO are aiming to conclude the expert group, progress to the working group and to raise the code mods required this year. However, there are a variety of external factors that may impact this timeline. Within this work the future position for mandating Grid Forming will be set out.
How many GBGF-I plants have reached ION and FON?	A number of GBGF-I sites are at various stages in the operational notification process; however, we are not able to comment on the precise number of plant types in each stage.
How many hours have the GF Expert Group spent in meetings in the last year? Where is the work of this group disclosed and published on the NESO web site? How many workgroup members are there?	The Expert Group is an informal stage of the overall code change process; NESO do not track the exact number of members or the time given by members of the group. Noting that this time is given voluntarily by the members of the workgroup.

	The Workgroup materials are distributed directly to participants, please contact box.GBGFGridCode@Neso.energy for any further queries.
during "onsite compliance testing", how are frequency events tested/generated? (rocof, phase jumps, …)	NESO appreciates that it may not be possible for the User to conduct the onsite compliance testing as per ECP.A.9 requirements involving Rate of Change of Frequency RoCoF and Phase Jump events on the total system. Therefore, the expectation is that a Factory Acceptance Test environment is used to assess the Grid Forming Behaviour.
Is FAT described in compliance testing applied to a single inverter or an entire plant?	It would be expected that a Control Hardware in the Loop (CHIL) test setup involving physical hardware of power converter controllers in combination with the Power Plant Controller would be used to demonstrate the Grid Forming plant behaviour and also to ensure there are no adverse control interactions during the FAT. As per the currently published guidance notes, we would recommend having at least two physical converter controllers used during the FAT. The total capacity of the whole setup is recommended to scale up to the total capacity of the plant in specific projects.
Does NESO consider phase angle jump withstand as an essential "service" or metric in evaluating technical requirements? e.g. must a plant remain within linear current range for a jump of X° in order to be considered technically viable?	NESO considers the Phase Jump angle event as a grid forming performance metric. The linear operating mode is characterised by the Phase Jump Angle Limit which is a threshold of operation between a linear and non-linear operating mode. Currently the Grid Code does not specify a specific phase jump that the plant must remain within its linear operation in order to be considered technically viable.
Is there a plan in the future to further segregate the GBGF-I requirement based on technology?	There is no current plan for this, but we are happy to receive any feedback for such consideration
What is the basis of damping factor proposed? Thanks	The Grid Code specifies the Damping Factor as being between 0.2 and 0.5 the Original Equipment Manufacturer (OEM)/Developer is expected to tune the parameter to make sure the adopted damping factor is the optimised value.

Is there a role for large grid emulators in the compliance testing process for GFM? What level of FAT has been done for GFM plants currently operational?	The FAT test process generally involves small test networks used to test the plant performance on an inverter or equivalent full site level. NESO cannot comment on the specific FAT that has been followed for currently operational GFM plants.
NESO's Best Practice Guide specifies a response time of 1s for Active RoCoF Response Power (ARRP). My question is HOW much ARRP is expected within this timescale?	There is no minimum requirement from NESO on this aspect as it is not a mandated requirement in the Grid Code.
For the medium voltage grid, generally type B & C generators are connected. Do we need similar compliance testing as you showed in the presentation?	For Grid Forming Plant including Type B, Type C and Type D generators, all the test requirements are the same.
Why does NESO require RMS models to be open? And how can providers maintain IP?	This is not in the scope of the webinar, further detailed on model submission can be found here: https://www.neso.energy/document/316631/download
Will you distinguish in future Grid Code modifications on Grid Forming the GF IBR, e.g. BESS vs Synchronous machines requirements? Inherent behaviour and controlled behaviour will generate some different results	Within the Grid Code currently there are different requirements for IBR Plant (GBGF-I) and synchronous plant (GBGF-S). Currently NESO do not intend to propose changing this.
Could you please outline the reasons why the GFM-I units did not meet specific technical criteria in the Y-1 Stability Market tender / In the recent Y-1 Round 2 Inertia tender, based on the public results, all grid-forming IBR plants (i.e. BESS) did not pass the technical feasibility stage. I realise a tender may have some specific requirements, but is this showing that the code is simply not updated yet to approve them or some other inherent issue?	The outcome of the most recent Y-1 Tender was not driven by technology type. Through the Network Services Procurement (NSP) process, NESO assesses all submissions against the published commercial and technical criteria, which are written on a technology-agnostic basis and can be met by a range of technologies, including grid-forming batteries. There are no criteria within the tender that inherently prevent grid-forming batteries from being successful. As with all providers, bidders were required to submit a fully compliant submission that clearly demonstrated how each element of the tender criteria was met, supported by sufficient and relevant technical and commercial

	evidence. In this tender, battery submissions were assessed in the same manner as all other technologies. Where submissions did not progress, this reflected how the submitted information demonstrated compliance with the criteria, rather than any exclusion of batteries as a technology.
Do we need to benchmark the FAT testing results with RMS/EMT models if yes what are the cases	The user is required to complete the tests as per ECP.A.9 in the Grid Code. This testing involves cases such as RoCoF, Phase Jump and FRT. These cases are then used to validate the testing results with RMS/EMT models.
In a network, there will be different types of GFM & GFL present. Can they support each other? Also, do all GFMs from different manufacturers cooperate each other during a fault condition?	As part of our network planning process NESO identifies where the system may need further services provided by Grid Forming Plant. Within the Grid Code, a minimum performance requirement that Grid Forming plant must meet is set out. This includes the performance during fault conditions.
With regards to recently published phase angle jump guidance, NESO state they expect to always see an initial anti-phase MW response to phase jumps. However, in simulations, we have seen large phase angle jumps that cause the GFM inverter to enter current limiting mode, and we can see a transient MW response in the "wrong" direction, before the GFM virtual impedance loop takes over to limit the current. During the current limiting mode, the GFM no longer acts as a constant voltage source behind an impedance, and depending on initial operating conditions we can see a MW response in the "wrong" direction. This is then corrected when virtual impedance kicks in and provides the desired anti-phase response. Would this scenario be acceptable for NESO?	The soon to be published Guidance Document of Grid Forming Version 4 will provide further detail on the expected performance from Grid Forming plant for Phase Angle Jump simulations and tests.

At what stage/penetration level the presence of GFL inverters create an issue in the GB grid and quantitively how does GFM inverters help alleviate such issues? Can NESO share the study/report findings from such investigations? Are there any critical timelines and/or GFL/GFM penetration levels?	We are working on an investigation internally on this currently and will look to share results appropriately when able to.
What is the process to update the grid code, via stakeholder engagement? We feel the phase angle jump behaviour is not correctly represented during the withstand mode as it would exhibit current source behaviour for a brief time	There will be a Grid Code modification this year to further clarify the Grid Code technical requirements for Grid Forming plants. The Grid Code modifications undergo a standard code governance process where a working group is created and industry participants are encouraged to participate and contribute.
Should I introduce a Grid Code modification to oblige NESO to publish information on EON ION and FONs? Or will NESO voluntary provide such data, nothing that NESO publish information such as the TEC register and other data on numbers types etc of connections.	Grid Code Users are able to suggest and raise changes to the Grid Code.
After a plant becomes operational, will there be any follow-ups after each disturbance event to evaluate GFM performance?	NESO may choose to complete performance monitoring in line with the Grid Code requirements set out in ECC.6.6.1.9.
If NESO are going to mandate grid forming for IBRs will all the requirements also be mandated for synchronous machines? So applying all the GFM related modelling and compliance processes to all synchronous machines which are inherently grid forming?	The same modelling requirements currently apply to both Synchronous and IBR plants.
NESO requires Subsynchronous Oscillation (SSO) simulation studies. Would NESO provide	This is not in scope of this Webinar.

adequate network models including multimass data of machines?	
Why does NESO not include small specific voltage steps tests as part of the requirements and compliance processes for grid forming?	Grid Forming Plant are also required to complete the Voltage Reference injection tests as specified in ECP.A.6.5.