Webinar: Stability Enhancement of Utility-scale Renewable Energy Plants in Weak Grids

No.	Question	Answer
1	Does the strategy contemplate the addition of utility-scale or distributed energy storage systems? Both standalone and co-located with renewable resources?	Although the control strategies developed in our project were primarily intended for utility-scale applications, there are no limitations to their use at the distribution level
2	Stronger grid causes greater instability?	Not necessarily, if your VSG is not tuned properly, it can make your system unstable.
3	What are the simulation tools used for this work?	Primarily PSCAD, in some studies MATLAB/Simulink
4	Is there any established performance requirement for a power oscillation damping controller for GFMI/GFLI?	There are no established performance requirements for a power oscillation damping controller for GFMI. However, several efforts around the world are working on this topic for GFMI. Unlike GFMI, GFLI is not expected to provide power oscillation damping
5	For Regulated utilities which operate under a cost of service model, is there a way to incent more innovative solutions to allow for higher % of renewables?	There are indeed ways to incentivize utilities to incorporate a higher percentage of renewables in their energy mix, even under a cost of service model. Some of these methods include: Regulatory incentives: Governments can provide regulatory incentives, such as renewable portfolio standards, which require utilities to obtain a certain percentage of their power from renewable sources. Non-compliance can result in penalties. Financial incentives: Financial incentives can also play a big role. These can include tax credits or subsidies for renewable energy projects. For instance, a feed-in tariff pays a premium rate for renewable energy fed back into the grid.

6	Why in most of studies, weak grid is related to voltage performance? What about frequency stabilty?	It is actually both. When a system becomes unstable, we would lose both frequency and voltage. We should treat an IBR like a system, and when it becomes unstable, we will lose both frequency and voltage.
7	Is those capability curves for IBRs also driven by the inverter controls and OEM? IBRs behave based on controls vs. synch machines that are based on physics?	The capability curves for IBRs are determined based on their control and also the grid parameters and also the IBR rating, so a combination of a number of factors.
8	What's the motivation for expanding the PLL stability region when one can just use GFMI? Are there benefits using GFLI than GFMI under certain conditions?	Expanding the PLL stability region enables GFLIs to function effectively in both strong and weak grids, while GFMIs operate smoothly only in weak grids. Therefore, it is not a viable solution to simply replace all GFLIs with GFMIs
9	can you clarify on higher SCR system showing larger oscillations and lower SCR system showing smaller oscillations?	This scenario pertains to the integration of GFMI, which operates like a voltage source. In weaker grids with lower SCR systems, GFMI exhibits smaller oscillations as it can manipulate the PCC voltage magnitude and angle smoothly. However, in stronger/stiffer grids, GFMI faces greater difficulty in controlling the PCC voltage magnitude and angle, resulting in larger oscillations. Further clarification on this phenomenon can be understood from the small signal analysis of GFMI and power flow equations.
10	What is the cost to inverter manufacturers to implement the changes mentioned here to grid-following inverters, e.g., an updated PLL?	The proposed changes involve software-based solutions, making them cost-effective and easy to implement. They only require modifying the inverter controller algorithms.
11	Any recommendation on criteria to adopt one of these many solutions for improved IBR performance? Using GFLI w/ non-linear controller vs GFMI vs SynCond	Identifying the optimal solution is a challenge. However, ongoing projects and studies worldwide are investigating all potential solutions, with particular emphasis on GFMI.
12	Merits of many small mass-produced synchronous condensers installed on the distribution system vs. few large synchronous	Small mass-produced have the possibility of being installed in various locations as compared to a large one, maximising their impact, as the location of SynCons play a big role in their level of impact. Additionally, distributed

	condensers on the transmission system?	SynCons will have the added benefit of higher reliability as not all of them will be out-of-service at the same time for maintenance or failure.
13	Should we be recommending that ALL GFL inverters use the Power Synchrnoized GFL controls? What is the downside?	Based on the promising results obtained with Power Synchronized GFLs, it is definitely worth recommending this solution to the industry. To the best of our knowledge, there are no significant downsides to using Power Synchronized GFLs, especially the fourth version (v4), which can operate smoothly under various grid conditions, including severe unbalanced events
14	How do regulatory policies impact the stability enhancement measures implemented in utilityscale renewable energy plant, particularly in region with weak grids?	The integration of renewable energy sources into remote areas with long transmission lines can result in weak grids. To mitigate this issue, current policies require studies to be conducted prior to connecting renewable energy sources to the grid. If any instability issues are identified after the connection, solar and wind farms may be asked to reduce or cut their power output to prevent further grid instability. For example, the Australian Energy Market Operator (AEMO) recently asked solar farms to reduce their output in response to challenges in maintaining grid stability in remote West Murray. This demonstrates the importance of anticipating and addressing potential grid instability issues before they occur
15	Should we assess weakness of the grid also after integrating the renewable energy?	Currently, there are no connection requirements to assess the weakness of the grid after integrating renewable energy sources. However, it should be noted that several recent concerns, such as subsynchronous oscillation, can only be identified after integrating renewables. Therefore, such considerations may be taken into account in future studies/connection requirements.
16	How could we assess the weaknes of a power system?	The short-circuit ratio (SCR) is a widely accepted index used to assess the strength or weakness of a power system or grid. It is calculated as the ratio of the short-circuit capacity at the point of common coupling (PCC) to the rated capacity of the inverter connected to the grid, represented as S_grid/S_inverter. Typically, the strength of a power grid is evaluated as strong when the SCR is greater than 3, weak for $2 \leq SCR \leq 3$, and very weak for $SCR < 2$.

17	Can the system stregth index that you have developed be relatively easily applied in operations?	Since it mainly requires the knowledge of inverter control, which are not necessarily available to operators, it is not straightforward to use this index in operations. .
18	What was the baseline system strength metric based on?	Currently, the baseline system strength is based on the fault level and how the system is far from the instability. To do so, the evaluation of the system strength is categorised based on a well-known index called the short-circuit ratio (SCR: the power grid is strong for SCR>3, weak for 2 ≤ SCR ≤ 3, and very weak for SCR < 2.
19	How to implement virtual resistance in real converters and what is the value of VR? Thanks	The virtual resistor is implemented in the control software of a converter. It can be treated as additional gain or a control loop in the control system of the inverter. Virtual resistance (or virtual impedance) can be used for various purposes, such as damping enhancement, decoupling P and Q, overcurrent limiting. Depending on the desired purpose, the value can be set accordingly. For the presented VR implemented for post-fault oscillation damping, the VR value is adaptively adjusted based on in order to ensure the desired dynamic performance the rate of change of the active power in fault recoveries. Limits of the VR are set, based on the rating and the line capacity, to prevent causing instability.
20	The adaptive tuning work showed results from changing SCR. Was the system inertia held constant in these cases? How would change in inertia affect this?	Adaptive tuning of the VSG involves changing the inertia in addition to other parameters to achieve the desired dynamic performance. However, it is important to note that the amount of change to the inertia should not be excessive, as demonstrated by the related results presented in the paper
21	What are the main differences between grid following inverter and grid forming inverter?	A grid-following inverter operates as a current source and requires synchronisation with the grid voltage at the point of common coupling (PCC). In contrast, a grid-forming inverter operates as a voltage source and is able to form (control) the PCC voltage without needing to synchronise with the grid voltage at the PCC.

22	Based on your research, can you say if both grid forming and SynCons are needed to achieve high IBR operation, or is it more optimal to go just with one tech?	The current research investigates both solutions, however, the more attention is being given to grid-forming inverters. The grid-forming inverters can provide several services including frequency support, low cost maintenance and black start as well as the possibility of operating in both grid-connected and islanded modes. However, the grid-forming inverters have low fault current capability.
23	Did you identify any trends from your tuning work, e.g. for stronger grid need to increase / decrease J / D?	Yes, as the grid becomes stronger, the J parameter decreases and D parameter increases in order to effectively suppress oscillations.
24	How is the stability matrix impacted with multiple manufacturers inverters?	Not sure what stability matrix this question is referring to.
25	Are the testbeds used for these projects shareable?	Absolutely, our laboratory test-based research is readily shareable, and we welcome opportunities to collaborate with both academic and industry partners. Please feel free to contact us to discuss potential collaborations.