NAME : Mark Norton
COUNTRY : Ireland
REGISTRATION NUMBER : DLG5517

GROUP REF. : B4
PREF. SUBJECT : PS1-PS3
QUESTION N° : S.1

Question 1: "Grid forming" is a generic term for many functionalities and ancillary services that can be provided by the PE based systems and equipment, e.g., black start capability, synthetic inertia, VSM, contribution to short circuit current, ...etc.

- *Does the industry need to develop a standard definition of grid forming functionalities including details of controls, response time, ramping rate?*
- *Which challenges are foreseen with large integration of PE-based ancillary services? What industry contributions are needed to enable large integration of PE-based ancillary services?*
- *The number of VSC grid forming converters (GFM) is still very limited to pilot projects around the world and very conceptual EMT simulations. What is the experience of these VSCGFM projects?*

Grid Forming Challenges and Mitigating Modular Technologies

Grid Forming Services have focused on third parties equipment, offering a service through ancillary services, rather than the equipment that makes up the grid itself.

Standard Definitions

As with the resolution of all network related issues there is a risk that highly bespoke and diverse solutions are sought globally by system operators, that consequently drive higher costs and overly complex equipment. The creation of a unified understanding of the portfolio of services that make up Grid Forming Services would be instrumental to mitigate this risk.

In Europe, the connection network codes[1] sought to provide a unified thinking of system operators. This has evolved over time to a set of grid forming services that are currently the subject of focused research[2]. A globally unified set of functional requirements and range of services built upon the work done to date, via a Cigre TB and ultimately IEC/IEEE type standardization would be a natural course of action.

Challenges with large integration of PE based ancillary services

The impact of a large integration of PE-based ancillary services is highly dependent on the PE devices being installed.

Renewable energy sources will form a major portion of future energy supply and most will be PE-based. It is inevitable that any challenges that arise from these devices must be mitigated. Reduction in system strength will occur, and as a result in AC networks, harmonic related problems, power quality, sub-synchronous resonance, and temporary overvoltage problems will become more common. These problems are mostly due to the underlying system strength conditions.

However, many other (non-renewable energy) PE devices come with a negligible risk, or negative impact, notably by avoiding adding additional negligible physical reactance that traditional mitigating technology would[3]. As these other PE devices are digital, and fast acting, their response can be tailored to offer avoidance or mitigation of the problems discussed above.

The risk of unexpected controller interaction is a commonly cited problem. Many devices, due to their design, are inflexible in their size and controls, and as a result, their location in the network is also often limited and fixed. Modular technologies at their core are built to avoid these restrictions. They are best deployed dispersed, reducing the risk of interaction with other PE devices, whilst designed to work seamlessly together without unexpected controller interaction. They provide a greater range of options in location, relocation, size, and control. In

[1] https://www.entsoe.eu/network_codes/
[2] https://eepublicdownloads.entsoe.eu/clean-documents/RDC%20documents/210331_Grid%20Forming%20Capabilities.pdf
[3] I. Hosak, M. Longoria, 'Improving transfer capability without series compensation challenges', IEEE Power and Energy Magazine, April 2022 and

combination, these attributes make modular devices the lowest-risk approach and often provide mitigation to challenges that arise from other PE devices.

VSC GFM

One form of Voltage Source Convertor PE devices is the Modular Static Synchronous Series Compensators (M-SSSC) that have been globally utilized mainly to actively control power flows in the existing grid, but that can offer Grid Forming Services. They effect change by injecting a series voltage in quadrature to the line current (90° leading or lagging).

Of the Grid Forming Services that have been identified above, the M-SSSC has been either directly or has been shown can be applied to provide services directly to provide or to maximise the effectiveness of other services.

Forming of system voltage and **Countering any imbalance in system voltage** can be directly contributed to by the harvesting of energy from the network to which it is connected to inject voltage[4]. As the devices rely on sufficient current and not system voltage to generate a voltage injection their contribution is effectively immune to divergent system voltages and support has already been proven for this service. The devices are single phase allowing imbalances to be reduced or eliminated. To provide the required contribution, modularity allows simple scaling of the devices to match.

Ensuring adequate short-circuit power can be delivered by services that either affect the amount of short circuit power to ensure stability of operation that is required and/or a direct contribution of that short circuit power. The former maybe defined as services providing enhanced system strength. In this context M-SSSC has already proven its ability to rapidly react to changes in the system in milliseconds to reduce network impedance and strengthen the effective short circuit levels on the network[5].

Contribution to system inertia is a good example of the combined impact and synergy between technologies namely storage solutions (BESS) and M-SSSC that have also been widely studied. These hybrid solutions have shown greater technical and economic benefits. While BESS can operate synchronized as « virtual power lines » to avoid congestion scenarios and provide synthetic inertia, it has been proven that the installation of M-SSSC can optimize the charge and discharge cycles and can be used to inject and steer the stored energy to the areas of the grid where it is most needed. A special contribution for the C2 special reporting topic 2, question 2.3 concluded:

‘*In addition, as most meshed networks have underutilized transmission capacity …, M-SSSC can control the reactance to optimize utilization, leading to a smaller BESS capacity needed for the same congestion scenario. Additionally, the combination of BESS + M-SSSC can increase the safe operating scenarios by increasing overall system reliability and allowing for black-start capabilities.’*

Countering harmonic and sub harmonics which are magnified and occur more frequently, hence becoming more problematic as system strength is reduced. M-SSSC natural inherent attributes have been shown to have negligible risk and mitigate Sub-Synchronous Resonance[6] issues. Also, like many VSC based technologies offer the opportunity to actively supress super synchronous harmonics, but unusually does so with negligible risk of contributing to the problem by adding in significant shunt or series physical impedance e.g. a transformer, or capacitor that often create secondary problems.

Adverse Controller Interaction avoidance are generally triggered by changes to system conditions either driven by changes in physical impedance or significant localised step changes on the network. M-SSSC as mentioned above do not add physical impedance, and with their modularity have been shown to be best when highly dispersed offering widely dispersed smooth changes that naturally avoid interactions[7].

[4] R. Fenlon, M .Norton, ‘Planning of an efficient power system with the use of modular static synchronous series compensation to enable flexible operational services’, CIRED Berlin, 2021
[5] R. Fenlon ‘An application of modular FACTS devices to relieve transmission constraints and accelerate wind farm connections and firm access’, 18th wind integration workshop, 2019
[6] I. Hosak, M. Longoria, ‘Improving transfer capability without series compensation challenges’, IEEE Power and Energy Magazine, April 2022
[7] D. Barron, A. Pashael, M. Osborne, D. Stamatiadis, P. Xenos, F. Madia-Mele, B. Marmaras, D. Schweer, ‘Real time dynamic performance, control interaction and protection studies of modular static synchronous series compensation technology in the Great Britain transmission system’, Cigre Paris, 2022