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GROUP REF. : B4
PREF. SUBJECT : PS1
QUESTION N° : Q.S1

Grid Forming Converters – A Solution to Future Grid

Part 1:
There is a need of defining a common understanding of the capability of a Grid Forming converter. The definition should allow the industry and the consumers of the technology to realize the boundary condition of the power electronic device. However, it should not put any constraint on the development of the Grid Forming controls to obtain the ancillary services possible by the hardware itself. The obtained experience from developed systems should shape the definition in direction of requirements or performance at the connection point, rather than a specific implementation algorithm.
In Siemens Energy view, the PE-based systems with Grid Forming control should be capable of:

- Providing the short-circuit contribution higher than a normal Grid Following converter
- Providing the inertia to the power system wherever applicable with the installed capacity
- Operating in a very weak system condition such as SCR < 1 including temporarily operating in the islanded network and supporting resynchronization with the grid.
- Provide inherent reaction (a concrete response time should adhere to the physical limitation of the hardware itself and without any additional control chain delay)

Based on applications Siemens energy foresees 3 different types of Grid Forming topology - this is not based on definition, it is the required feature which can be utilized from Grid Forming converters based on connection point. The three topologies are:

- **Islanding Grid Forming Converter**: Such solutions are applicable for islanded & isolated networks.
- **Grid Forming Converter without additional Storage**: Such solutions can be used for all three topologies: islanded, isolated, and synchronous networks. However, it is limited by the inertia that can be provided instantaneously with the respective converter design. In control methodology, this solution is the most challenging one as it ensures the maximum usage of converter capability up to transient design margins and co-ordination with the other converter stations via the DC link without any physical communication. In such configuration, multiple converters are Grid Forming capable and acts accordingly to the severity of the AC network disturbance.
- **Grid Forming Converter with additional Storage**: Such solutions have the added advantage of having local energy storage and are less dependent on the other AC network via DC link. Such solutions are extremely beneficial for STATCOM Frequency Stabilizer devices due to non-availability of the DC link connected to other AC energy sources.

Part 2:
In future more and more power electronic based systems are being connected in a broad transmission range which poses mainly following challenges:

- Decentralized connection due to penetration of renewables are non-uniform in an AC network due to availability of the sources
- Higher energy demand
- Digitalization of the assets for better utilization
- Decarbonization

Such decentralized approach will lead to a more mixture of AC and DC transmission system due to long bulk power capabilities of HVDC systems. In order to face those challenges, large scale battery storage solution will be required to stabilize the local areas ie sub-grids or microgrids.

The conventional current-controlled inverters are prone to interactions if located in close electrical proximity. Due to narrow range of harmonic damping provided by such Grid Following devices the challenge is not only voltage or frequency support but also harmonic stability of the connected AC network. The goal of Grid Forming should be reducing the risk of interactions between neighboring plants and enhancing the ancillary services available by converter utilizing the design margins. However, to confirm compatibility between Grid Forming assets, extended network investigations are necessary, which puts a constraint of requiring accurate models from different vendors with protecting vendor's IP know how measures of course. Any generic model in nature does not include all the converter internal limitations which at the end defines the performance a converter can deliver. Therefore, to meet this goal, different industry contributors require a standard demonstration path for compliance including impedance characteristics of the converter at the connection point of the asset.

Part 3:

Siemens Energy has experience of Grid Forming without additional Storage for HVDC applications and with/without additional Storage for STATCOM applications. The control philosophy is applicable for all current projects, however tailor-made solutions are adopted to meet the customers' requirements in terms of different grid characteristics and possible ancillary services from the asset. The Grid Forming control may emulate synchronous machine behavior, but not only limited to and prolongs the feature of – voltage/frequency control algorithm to give a wide flexibility to its user including black start capabilities. To achieve the tailor-made solutions, a wide range of EMT studies are performed with more accurate detail models consisting actual measurement systems and control algorithm. This ensures the EMT simulations are more comparable to the actual installed hardware.
There are several HVDC and STATCOM projects are under execution status with Grid Forming technologies - where the control solution is being tested in the real hardware and studies are being performed with detail Software models. Therefore, the development is no longer in conceptual study phase but in official product delivery phase.