B4 – DC SYSTEMS AND POWER ELECTRONICS

PS1 – HVDC SYSTEMS AND THEIR APPLICATIONS

PS3 – FACTS AND POWER ELECTRONICS

11088_2022

Methods and Requirements for the Upgrade of HVDC and STATCOM with Grid Forming Functions for Multi-Level Converter Topologies

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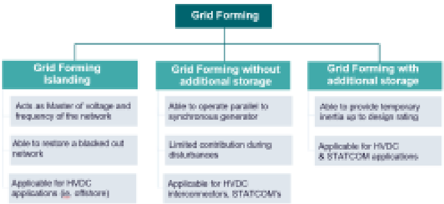
Motivation

- Increasing integration of renewable energy sources like wind and solar.
- Reduction of the inertia in the grid.
- HVDC and FACTS schemes come more into focus of how these applications can provide grid forming properties.

Design requirements

- Maintaining AC voltage and frequency stability in the connected area.
- Ensuring converter stability during large AC voltage/power angle steps.
- Operation in parallel to synchronous generator and other converters.
- Staying connected during significant short circuit impedance changes.

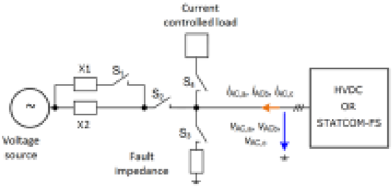


Objects of investigation

- Islanded or passive network: primary objective is to control the amplitude and frequency of the AC voltage of the network. Subsequently, if more and more loads are added, the converter shall be able to supply the energy from the interconnected DC link (other AC network) and remain in stable operation.
- Isolated network: a complete dominance of power converter is expected. For example, offshore energy being transported to the onshore. Therefore, lack of any synchronous generation to stabilize the amplitude and frequency of the AC voltage of the network as well as interaction between different power electronic devices will determine the stability of that interconnected network.
- Synchronous network: such kind of network generally ensures that there are some synchronous generators connected to supply the load and can be in the same range from the size of the relevant power converters (e.g. SCR = 1) up to several factors higher (SCR = 10 and above). Loss of the complete generation will lead to the Islanding or Isolated mode described above.

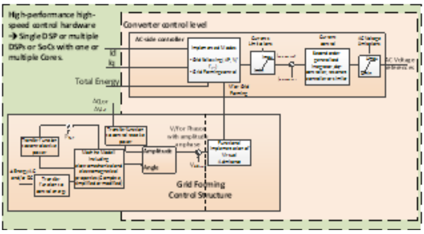
Experimental setup

- Controllable voltage source (voltage steps, angle steps and frequency ramps).
- Conventional current-controlled load.
- Adjustable fault impedance and SCR (including isolated operation).



Final structure

- Inherent, passive change of the current vector, in amplitude and angle, caused from the change in the network voltage vector.
- Tracking of the converter voltage vector to reach stationary reference values for the active and reactive power.
- Limitation of the current and voltage vectors within values compatible with the installation design. Limitation against losing synchronism with the grid.
- Control structure operational switchover between Grid Forming ↔ Grid Following.



Conclusion

- Grid Forming converters are beneficial for the network stability.
- The Grid Forming control solution is not only foreseen for new converter installations, but also it can be applied to the existing systems, if necessary hardware is available.
- Similar approach for converters: HVDC or STATCOM Frequency Stabilizer, gives a more harmonious solution between different types of application.
- The Grid Forming control gives flexibility in terms of final performance, which can be adjusted individually to meet requirements of each application.

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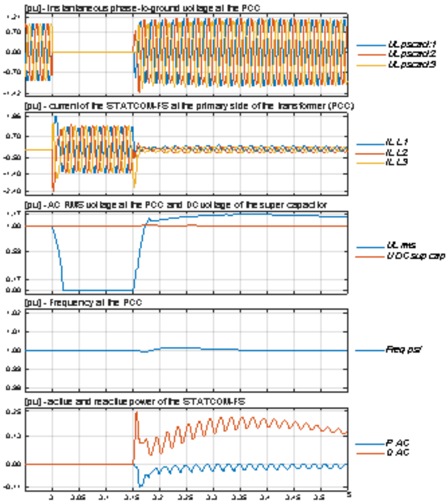
Continued: STATCOM-FS

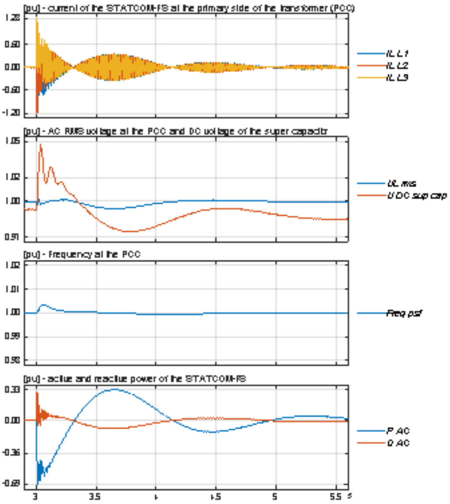
Three-phase fault

Providing short-circuit current.
Minor contribution to the overvoltage after the event.



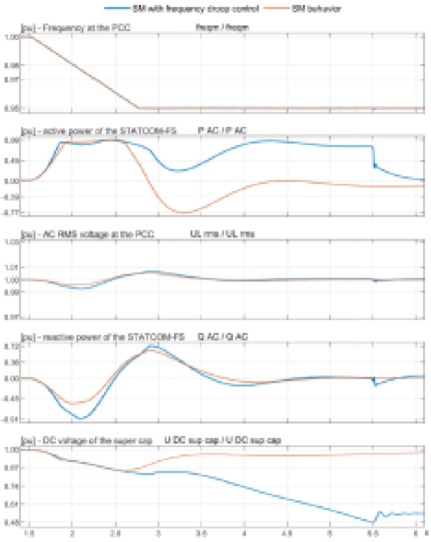
Angle step +30°

Instantaneous reaction on the angle step against the network changes.



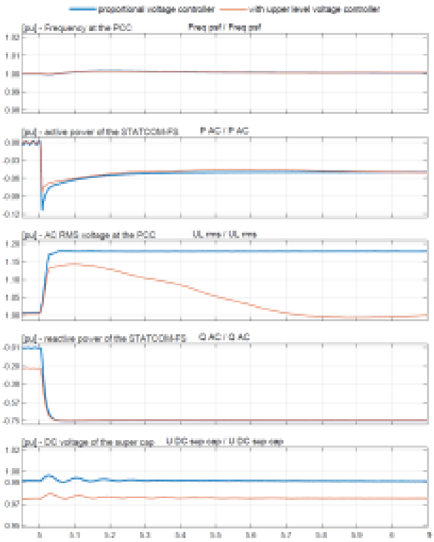
Linear frequency change

STATCOM-FS emulates a synchronous machine behavior; possible follow up with frequency droop control to temporarily balance the grid (until discharged).



Islanding

Immediate overtake of the supply of the current-controlled load by the STATCOM-FS; can also be followed by the steady-state voltage control.



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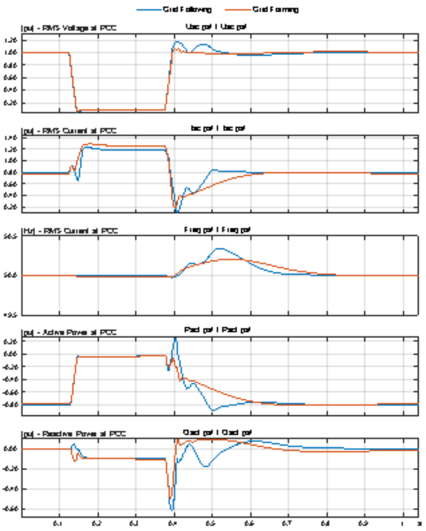
Continued: HVDC

Three-phase fault

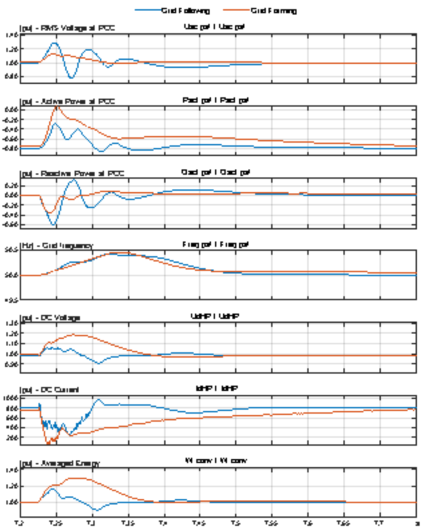
Instantaneous current injection and voltage source behavior for Grid Forming control → less overvoltage and well damped response.



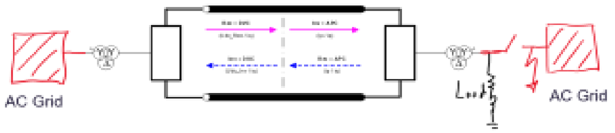
Angle step -40°

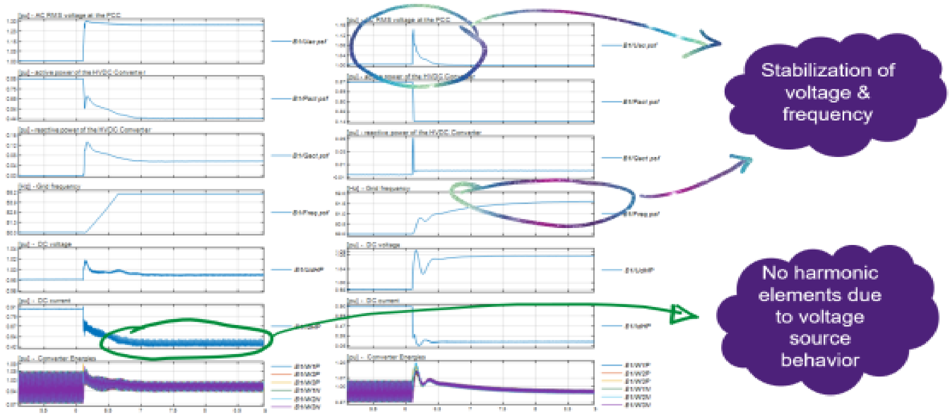
Voltage source behavior for Grid Forming control:

- instantaneous active current injection,
- reactive current counteracts voltage changes.



Islanding: Grid Forming vs. Grid Following





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