Harmonic Interactions – Observations and Mitigations

Undesired high frequency harmonic interactions between FACTS or HVDC system and connected AC system have been observed and resolved. Higher risk for their occurrence appears in the following cases:

- Long AC cables at converter side
- Cable dominated AC grids (e.g. offshore grids)
- Stray capacitances in OHL with high grid impedance
- Unfavorable HF filter designs (e.g. tuned at or near effective switching frequency of converter)

In general, real converter control systems have limited bandwidths and delays in measuring, communication, signal processing and actuators (e.g. semiconductors).
Therefore, it is a matter of fact that negative damping effects (harmonic impedance of converter) occur at some given frequencies.
Observed harmonic interactions for HVDC and FACTS devices are typically in the range of 1 kHz to 4 kHz (it is expected that skin effects and other effects leads to a positive damping at higher frequencies). Therefore, the implementation of an appropriate protection mechanism is recommended for commercial HVDC or FACTS to avoid equipment damages.

To avoid or mitigate harmonic interactions in that frequency range a comprehensive analysis of and modelling of the system is necessary:

- Accurate modelling of the connected AC system, primary components (including their parasitic elements) and control algorithms for the relevant frequency range for the relevant system configurations and operating conditions.
- Harmonic impedance analysis of the whole modelled system to identify critical frequency ranges.

Following mitigation measures on the station and in the AC grid can be considered:

- Reduce or avoid cables
- Damping circuits / HF filters
- Exclude critical system

However, these measures are often not feasible in real projects. Therefore, an appropriate converter control design with short delay times is mandatory. Furthermore, based on the analysis and modelling mentioned above considering also harmonic content from the grid structural and parameter optimizations of the converter control are necessary to achieve an optimum trade-off between transient response and robustness.