Study Committee C4
System Technical Performances

Paper 10724

Electro Magnetic Transient Simulations for risks assessment of a live black start test of an HVDC VSC

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Motivation

- Blackstart test performed on a new 1GW HVDC VSC involving 3rd party assets (HPP owner)
- Previous blackstart tests on a different HVDC have shown risk of resonances in case of sequential blackstart➔ soft energization is used
- Very limited experience of tests using HVDC VSC for blackstart in a network with large active assets
- Risks had to be assessed before tests to reassure all the stakeholders involved

Detailed EMT simulations to assess the risks

- The tests involved energization of the islanded network, connection of large load (pump) and generators (turbine) and the resynchroniztion
- EMT simulations with detailed model : geometric model of the OHL, full scale model of the HVDC, detailed model of the pumps and turbines (with governor and AVR/exciter)

Oscillations due to interaction of parallel OHL at different frequencies

- Oscillations have been observed in the simulations and in the measurement at complementary frequencies (f1+f2) and (f1-f2) of the islanded network (f1) and the continental European one (f2)
- The origin of the oscillations is the interaction is the electromagnetic coupling of un-transposed conductors on the same tower operated at different frequencies
- After assessment, the oscillations have not been considered a risk for any of the assets involved in the blackstart

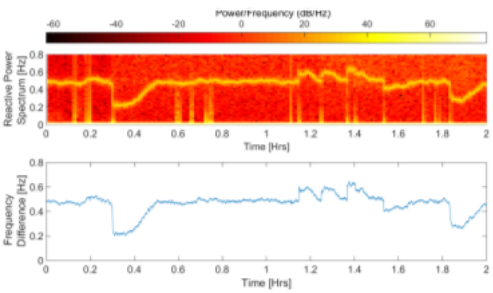

Figure 2:Measured reactive spectrogram (top) and measured difference between the frequency of the parallel OHLs on the same tower during the tests (bottom)

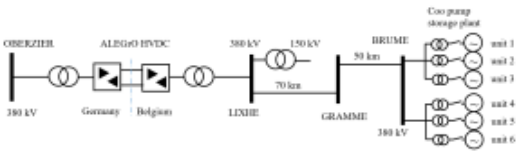

Figure 1: Simplified SLD of the black start test network

Overvoltages in case of blocking of the HVDC converter

- In case of specific short circuit when operating at high pre-fault current the HVDC blocks and trip
- As consequence of the block, considerable overvoltages are appearing in the islanded network
- EMT simulations have confirmed the limited risk of these overvoltages being compatible with the surge arresters energy capabilities

Conclusions

- EMT simulations have allowed to detect two main risks: **sustained oscillations of active and reactive power** and risks of **overvoltages as consequence of blocking** and trip of the HVDC in case of metallic single phase short circuits.
- The **first** risk is **detected during simulation and confirmed during the test**. This phenomenon has been considered **acceptable by the different stakeholders** involved in the tests.
- The **second** risk **has not been encountered during the tests**, but the consequences of **temporary over voltages**, shown during simulations have been considered **acceptable after correct modelling of surge arresters.**
- A **correct model of the injectors** as well as the **transmission asset** is needed to **accurately** represent the **phenomena**, **detect** potential **risk** and **assess** possible **mitigation measures** to **maximize the chances of success** of the test and **minimize the risks on asset damages**.

Detailed EMT simulations are fundamental to derisk complex black start tests with presence of power electronics devices.

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Interaction between the OHL on the **same tower running at different frequencies f_1 and f_2** gives rise to RMS voltage modulation at a low frequency **difference of the two f_low= |f_1-f_2|**

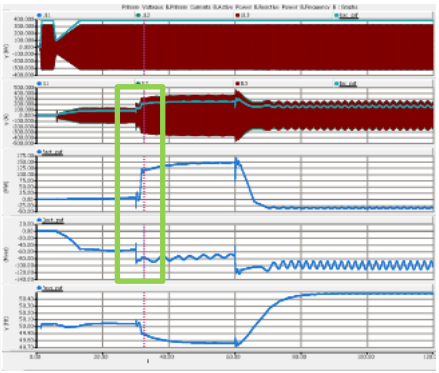

Figure 3: Exemplary oscillatory **simulation** of the blackstart sequence. From top to bottom: voltages, currents, active power, reactive power and island frequency at the terminal of the HVDC.

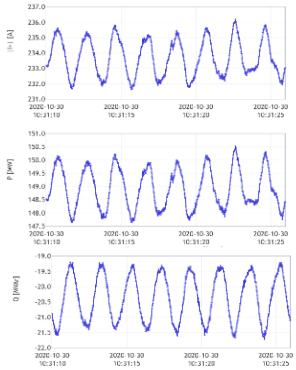

Figure 4: Exemplary oscillatory **measurements** from the blackstart tests. From top to bottom: positive sequence current, active and reactive power measured in the substation Lixhe.

Interaction between the OHL on the **same tower running at different frequencies** f_1 and f_2 gives rise to positive sequence RMS voltage magnitude oscillations at a **high frequency sum of the two f_high=|f_1+f_2|**

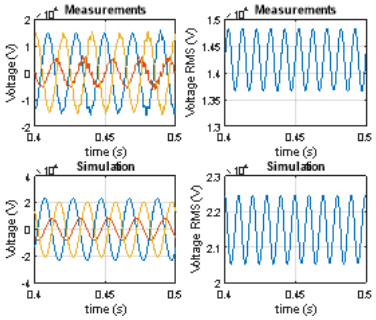

Figure 5: Presence of the higher oscillation frequency $f\_high = |f\_1+f\_2|$. Comparison between measurement (top) and simulation (bottom) of instantaneous voltages (left) and RMS value (right). The voltages are measured at Lixhe at the beginning of the test with the islanded network not yet energized.

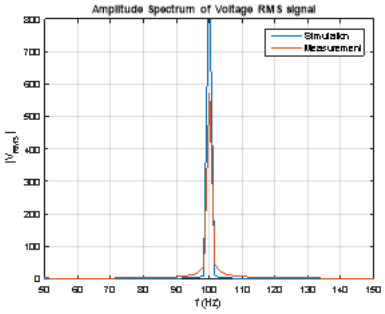

Figure 6: Comparison of the amplitude spectrum between measurements and simulations

Oscillations are unharmful for the stability of the power systems during blackstart tests and not present during a real blackstart. Similar behavior is expected on systems with OHL with mixed AC and DC systems

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For a specific single phase to GND metallic short circuit, the HVDC blocks after few milliseconds due to a valve current overload and trips. This behaviour is in line with known HVDC limitations, its side effect is that the phase voltages rise to an extremely high value (up to 1000kV) that is a non-acceptable.

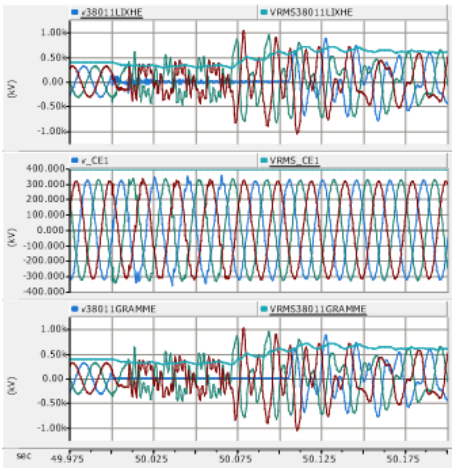

Figure 7: Waveforms in case of single phase short circuit with blocking of the HVDC **without surge arrester modelled**. From top to bottom: three phase voltages and RMS in Lixhe, close to the HVDC, on the parallel OHL line and in Gramme close o the HPP.

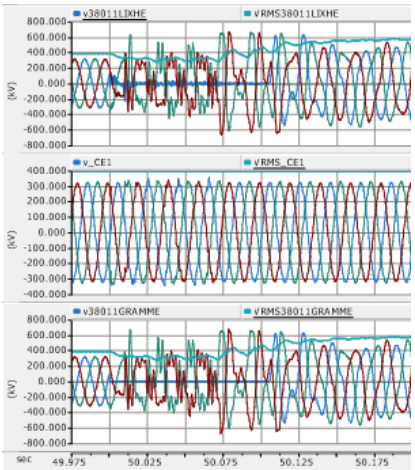

Figure 8: Waveforms in case of single phase short circuit with blocking of the HVDC **with surge arrester modelled**. From top to bottom: three phase voltages and RMS in Lixhe, close to the HVDC, on the parallel OHL line and in Gramme close to the HPP.

After having modelled the surge arresters, the simulation showed lower temporary overvoltages.

This has been considered acceptable considering the low probability of such incident during tests.

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