Study Committee C4

Power System Technical Performance

10819

Virtual C&P – A powerful simulation platform for HVDC and FACTS in present and future grids

J. HERNANDEZ[1], E. KILANDER[1], S. AUDDY[1], K. A. MITSCH[2], M. MEISINGSET[3]

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Motivation

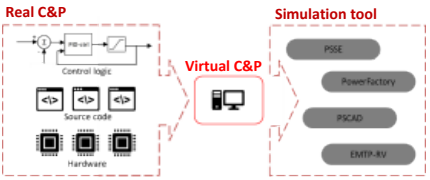
- There is an unprecedented increase in the market of HVDC links, both offshore and onshore. New strategies to decrease design and commissioning times are necessary.
- Traditionally, C&P system are designed, validated and implemented C&P systems in the online domain using real-time simulators (RTS).
- Both offline and online simulations are key to ensure the quality and decreasing lead time for effective commissioning of the C&P system.
- However, there is historical believe in the industry that offline simulations are less accurate than online simulations. Thus, many studies are requested to be done using online simulations.
- BUT, compared to offline simulations, online simulations require:
  - (i) more physical space for C&P cubicles, operator desktop computers, RTS hardware cubicles and desktop computer with RTS software.
  - (ii) more time to perform studies, as they often cannot be run in parallel, if no replica system is available.
  - (iii) more installation and setup time to mount all hardware, drag and pull all cables, connect them and setup the simulation environment.

Contribution of this paper

- ***What more can be done using offline simulations to speed up the design, validate and implement a C&P system, while quality and performance is ensured?***
  - (i) Present a digital twin of the real C&P system and its key features.
  - (ii) Present performance results by comparing offline EMT simulations using the virtual C&P framework and real site measurements.
  - (iii) Present main factors affecting the performance results.

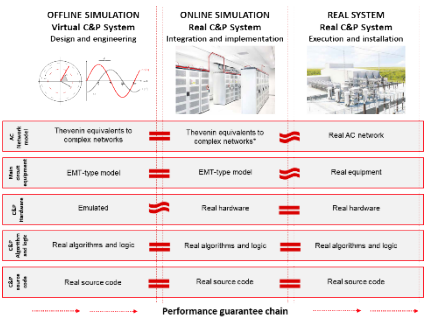
Virtual C&P and offline simulation

- The key technical aspects to achieve an accurate virtual C&P system framework are:
  - (i) Use of the same source code and logic for both the virtual and the real system.
  - (ii) Accurate emulation of measurement devices i.e., measurement sample time, filters and communication delays from the measurement device to the control system are the same as the real system.
  - (iii) Accurate execution of the control and protection applications i.e., tasks are executed in the correct order and at same sample times as the real system.



Effective engineering during and after project

- Transient stability studies are performed using RMS simulation tools to design and analyze the behavior of high-level controls.
- Transient and dynamic performance studies (DPS) are conducted using offline EMT simulation tools to design and analyze the behavior of lower-level controls.
- After-sales support for fault investigations and pre-studies for future upgrades can be provided.



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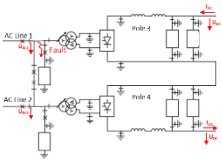
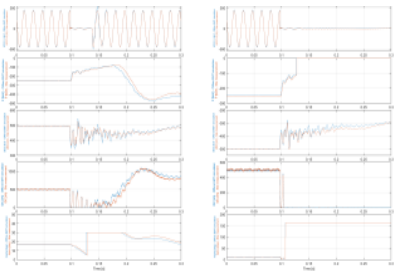
Comparison between offline EMT simulations and real installations' recordings

LCC HVDC – Pacific DC Intertie

- The Celilo HVDC converter station was upgraded on 2016 with a transmission capacity of 3,800 MW at ±560 kV.

- During the commissioning, a single line AC staged fault was created on the AC filter bus of pole 3 to verify the performance of the AC protections.

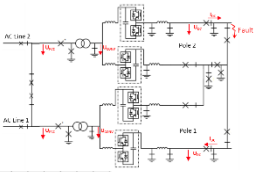


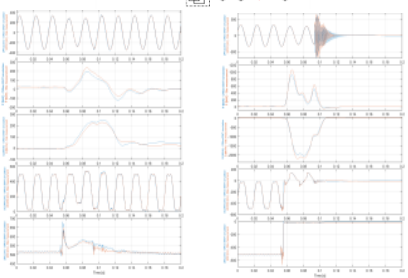


VSC HVDC – NordLink

- The Ertsmyra HVDC converter station was commissioned 2020 with a transmission capacity of 1,400 MW at ±525 kV.

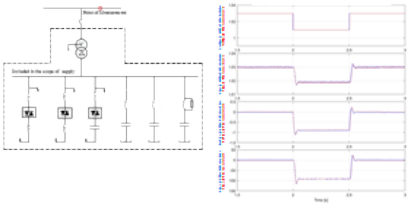
- During the commissioning, a negative pole staged fault was created to verify the performance of the DC overhead line protection.





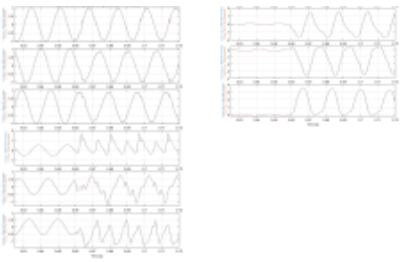
LCC FACTS – Utility case study

- In 2021, a utility Static Var Compensator (SVC) based on a thyristor switched reactor and capacitor was installed in North America.
- During the commissioning, an AC voltage step response test was performed.



VSC FACTS – Industry case study

- In 2016, a VSC-based STATCOM in a steel plant in North America experienced a trip.
- The trip was caused by the valve overcurrent protection during the transformer energization of an electric arc furnace.



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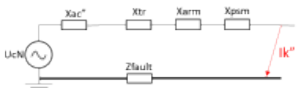
Discussion and results interpretation

- The ultimate goal of any model is to serve as a digital counterpart of the real system. Thus, models should in principle be validated against the real system.
- CIGRE Technical Brochures 864, recommend to validation of offline models against online models. The idea behind, is to validate the virtual C&P system against the real C&P system.
- The recommendation, however, does not ensure the model is capable to accurately predict the behavior of the real C&P when connected to the network. This is done during commissioning at site.
- The presented approach ensures a complete coupling between offline and online models. So, the validation of offline models against online models is irrelevant.

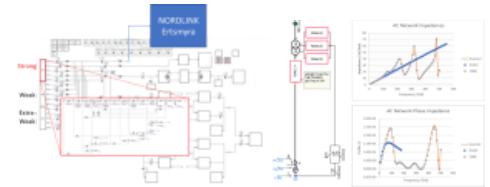
Electrical EMT model representation

- Accuracy is affected by the electrical representation of the AC network impedance, the station grounding impedance, the measurement equipment and nearby AC/DC lines interactions.
- The AC network representation is one of the major affecting parameter. If no information is available estimates are required to overcome this task:
  - (i) Estimate of AC network SCC and X/R
  - (ii) Perform frequency scan of the AC network Z(f)
  - (iii) Decouple AC network positive (Z+) and zero sequences (Z0) impedances
  - (iv) Run parametric studies to find a suitable representation

$$I_k'' = \frac{\sqrt{2}\cdot IvN}{Xac\%+Xtr\%+Xarm\%+Xpsm\%} \qquad Xac'' = \frac{Uc}{\sqrt{3}\,IvN}\,\frac{Xac\%}{100}\,tr^2$$



$$SSC = \frac{U_N^2}{Zcc} \approx \frac{U_N^2}{Xac}$$



Virtual C&P system representation

- The source code of the C&P system is compiled using an external compiler. This, is perceived sometimes as a drawback of offline models, often referred as compiler dependency.
- Online models are not only compiler dependent but also hardware dependent.
- Compiler dependency is caused by the compiler language backward compatibility between main versions, and it is not related to either offline or online simulation.
- HVDC links of bipole configuration require that synchronization between both poles' control systems are respected for each time step.
- Simulations at extremely low power orders in relation to the converter nominal power require higher precision between the EMT model and the virtual C&P system.

Conclusion and recommendations

- Offline simulations based on virtual C&P systems can capture the dynamic behavior of the real system.
- Alignment against the real system can only be achieved when both the EMT electrical representation and the virtual C&P system are accurately represented.
- Virtual C&P systems permit engineers to work in parallel and permit to investigate and integrate complex models in a flexible, scalable, and efficient manner, without the need for additional hardware.
- Virtual C&P systems can reduce the time needed to design, validate, and implement the C&P system, without compromising on accuracy.
- Given the accuracy presented, in order to avoid duplication of tests, it is recommended that online simulations focus on:
  - (i) functional testing of hardware
  - (ii) system supervision
  - (iii) testing of project specific functions affecting low frequency upper-level control
  - (iv) testing synergies, interactions and/or dependencies between control and protection
  - (v) integration of customer induced sub-systems (SCADA)