The use of real time simulation to de-risk and manage HVDC and FACTS schemes

Experiences on the French Transmission grid
Introduction

Several power electronic devices (HVDC and FACTS projects) are currently planned or constructed by RTE

- Considerable impact on the grid performance and reliability
- HVDC and FACTS include control system and protections
- Dynamic behaviour much more complex compared to standard AC devices
- Requiring skills and tools dedicated to this technology
Introduction

2011

Creation of the real-time simulation laboratory: SMARTE in Paris La Défense

2017

Control system replicas are acquired and installed in this laboratory for each new power electronics project on the French grid.
HV power electronic Projects

- **FAB**
  - France Aldernay, Britain
  - 1400 MW - 2022

- **IFA 2000**
  - réglage fr/p - 2015

- **IFA 2**
  - 1000 MW - 2020

- **Eleclink**
  - 1000 MW - 2018

- **Celtic Interconnector**
  - 700 MW - 2025

- **France Spain**
  - Golfe de Gascogne
  - 2*1000 MW - 2022

- **Piémont Savoie**
  - 2*600MW 2019

- **Midi Provence**
  - 1000 MW - 2020

- **France Spain**
  - 2*1000 MW - 2015

- **IFA 2**
  - 1000 MW - 2020

- **Midi Provence**
  - 1000 MW - 2020

Legend:
- **Existing**
- **Decided**
- **Studied**
- **Private**
- **SVC**
- **Decided Offshore Wind farm**
Typical life cycle of EMT models

Design & engineering studies
- Offline EMT model
- Preliminary control system

FPT/DPT
- Offline EMT model (final version)
- Real-time simulation with physical controls

On site commissioning
- Software may be updated
- Measurements compared to DPT

Commercial operation
- Black box EMT models delivered to customer

Model may be different to the software on site
Specific issues for EMT models

- **Validity**
  - Difficult to follow software version

- **Long term studies**
  - Shall be available in 10/15 years?
  - How to maintain it?

- **Functions**
  - Limited functions to speed up the model
  - Simplified controls because of CPU performance

EMT offline models are mandatory to perform accurate studies

RT simulation can provide validation and update on a long term of the offline models
Issues with offline models

Real event occurred on an LCC scheme after refurbishment: control system disoperation, followed by protective valve bypass and finally main CB failure due to current zero crossing delay.

- First attempt: analysis with the offline model provided by the manufacturer → virtually impossible to recreate the event even with the manufacturer support
  
  ![3ph current in main AC CB](image)

- Second attempt: analysis with replicas with the same software on site → event successfully recreated

  ![3ph current in main AC CB](image)

- Software on site was different than in the model
- Engineers initially involved in the model development left the manufacturer company
- The offline model only ran on old OS
Replica overview

A replica is an exact copy of the actual control and protection system installed on site.
Replicas for HVDC/FACTS

Replicas scopes:

- Develop skills and knowledge on HVDC and FACTS systems
- Investigate interactions phenomena related to HVDC and FACTS devices
- Training engineers and support maintenance activities
- Improve specification and optimize system performance
- Validate future software update
- Network studies and improve offline models
- Studying and testing multi-vendors and multi-infeed schemes
Real-time lab with HVDC/FACTS replicas

Located in Paris with every HVDC/FACTS control systems connected to the French Transmission System (including controls for wind generation)

Replicas connected to real-time simulators (Hypersim and RTDS)

Hardware installed in the RTE lab from 2013:

- 5 SVC replicas from ALSTOM Grid (Merlatière and Domloup project) and SIEMENS (NANTERRE project)
- 1 HVDC LCC replica from ALSTOM Grid (IFA2000)
- 2 HVDC SVC replicas from SIEMENS (INELFE project)
- 6 real-time simulators (170 CPU) and IO cabinets

Staff: ~10 engineers
Replica type

A. Study replica

- The study replica is dedicated for functional verification, dynamic performance and protection studies.
- Only relevant equipment for network studies are provided.

B. Maintenance replica

- The Maintenance replica is intended to help the preparation of on-site maintenance operations and operator trainings. It includes testing and validation of the upgraded system version before field implementation.
- Maintenance replica includes identical cubicles to the on-site cubicles: same interfaces, redundant equipment, etc.
Real Time lab

SMARTE lab

- SVC MAINTENANCE
- SVC STUDY
- HVDC LCC
- HVDC VSC - MAINTENANCE
- HVDC VSC - STUDY
Typical event study using Replicas

1. Onsite event occur
2. Retrieve onsite data of converter station and AC grid
3. Check if event is inside or outside the station
   - If outside: check if HVDC has operated correctly
   - If inside: check if it is due to HV equipment, hardware or software problem?
     - Repeat the event on the replica
     - Perform sensitivity studies
     - Study mitigation solution
4. Exchange with vendors
Interaction studies with SVC controls

Domloup SVC replica
Merlatière SVC replica
Tourbe SVC replica

HMI PC
HMI PC
HMI PC

Hypersim network modeling and results analysis

OPAL-RT TECHNOLOGIES
Interaction studies with SVC controls

West 225kV grid modeling in Hypersim.

West grid: lack of production, antenna structure $\rightarrow$ Weak part of the French grid

- 24 substations
- 31 lines
- 3 SVC replicas
- 4 machines and controls
- 11 cores
Interaction studies with SVC controls

Event: 400kV line fault seen by the 3 SVCs

Observation of SVC regulation during the fault to support the voltage and after the fault to keep voltage stability during oscillation of Cordemais power
Tools for maintenance and training

- Operator and engineer training
- Develop skills and knowledge on HVDC
- Test hardware modification
- Network events analysis
- Test software update
- Integration of new development
Real-time model validation

- Before connecting the replica, real-time model is validated against offline model.
- In order to validate the power system component, the exact generic control system implemented in EMTP-RV and Hypersim is used.

**EMTP-RV model:**
(offline simulation)

**Hypersim model:**
(Real time simulation in SIL setup)

- Same generic control system
Hypersim model validation

Active/reactive power
Hypersim model validation

DC voltage/current and SPR current
IFA2000 Replicas validation

Pole-to-ground fault event on the IFA2000 link (November 2016)

Incident reproduction using Hypersim simulator and replicas
Example of studies with INELFE replicas

Resonance interactions between VSC controls and AC grids
- Network configurations can lead to harmonic interactions between AC grid and HVDC controls
- Accurate representation of AC grids and exact behavior of controls is needed
Parametric studies using replicas

### Parameters

<table>
<thead>
<tr>
<th><strong>Parameters</strong></th>
<th><strong>Values</strong></th>
<th># of config</th>
</tr>
</thead>
<tbody>
<tr>
<td>P/Q setpints</td>
<td>± 500 / ±150MW</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>± 1000 / ±300MW</td>
<td></td>
</tr>
<tr>
<td>Fault type</td>
<td>3LT, 1LT, 2L et 2LT</td>
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<tr>
<td>Short-circuit Level (PCC)</td>
<td>Pcc_max, Pcc_mean, Pcc_min</td>
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<tr>
<td>Fault impedance</td>
<td>10, 1 et 0.001 ohm</td>
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<tr>
<td>Fault duration</td>
<td>150 et 280 ms</td>
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</tr>
<tr>
<td>Fault instant (relative to AC voltage phase A)</td>
<td>0 à 17.5 ms par pas de 2.5 ms</td>
<td>8</td>
</tr>
</tbody>
</table>

- Total number of simulated test cases: $8 \times 4 \times 3 \times 3 \times 2 \times 8 = 4,608$ tests!
- Parametric simulations are conducted automatically using Testview software.
### Parametric studies using replicas

Parametric studies using replicas : Results are automatically generated

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<th>fault_type</th>
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<th>fault_instant</th>
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<th>Conv_Trip</th>
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<th>lpos_max_peak</th>
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THANK YOU

Questions?