CONVERSATORIO:

Sistemas HVDC

SESIÓN 1:
Aspectos claves del diseño y especificación de sistemas HVDC

HVDC Transmission Project:
Specification, Testing and Training

Proyectos de transmisión en HVDC:
especificación, prueba y entrenamiento

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CONVERSATORIO: Sistemas HVDC

SUMMARY OF TOPICS

- SPECIFICATION
- DESIGN REVIEW
- TESTING
- FACTORY TESTS
- COMMISSIONING
- STAFF TRAINING
DATA FOR SPECIFICATION

- INFORMATION ON THE AC SYSTEMS CONNECTED TO HVDC SYSTEM
- COMPLETION OF SYSTEM STUDIES FOR DEFINING THE HVDC SYSTEM REQUIREMENTS
- RESULTS OF ACTUAL HARMONIC IMPEDANCE MEASUREMENTS OF BOTH AC SYSTEMS
- INFORMATION ON THE CONVERTER SITE AND RELATED INFORMATION FOR CONSTRUCTION
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WHAT TO INCLUDE IN SPECIFICATION

- SYSTEM RATING
- PERFORMANCE REQUIREMENTS
- RIGHT TO REVIEW OF ALL STUDIES AND FACTORY TESTS
- LOSS EVALUATION CRITERIA
- LIST OF FACTORY AND COMMISSIONING TESTS
- PARTICIPATION IN FACTORY TESTING
- PARTICIPATION IN COMMISSIONING TESTS
### WHAT TO INCLUDE IN SPECIFICATION

- **SPARE PARTS**
- **WARRANTY PERIOD**
- **TRAINING OF OPERATING AND MAINTENANCE STAFF**
- **PSCAD, PSSE AND RTDS MODELS OF HVDC SYSTEM FOR STUDIES**
- **RTDS REPLICA FOR THE OPERATING STAFF**
- **RIGHT TO VIDEO RECORD THE TRAINING SESSIONS FOR OPERATING AND MAINTENANCE STAFF**
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DESIGN REVIEW

1. Contactor submits designs for all components
2. Designs are reviewed
3. Any concerns are discussed
4. If necessary, the design is modified
5. Designs are approved
TESTING
FACTORY TESTING

SITE TESTING

ALL TEST PLANS MUST BE APPROVED BEFORE TESTING STARTS

ALL TESTING SHOULD BE WITNESSED
# List of Tests

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off line tests</td>
<td></td>
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<tr>
<td>Energization tests</td>
<td></td>
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<tr>
<td>Open Circuit &amp; Open Line tests</td>
<td></td>
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<tr>
<td>Block/Deblock</td>
<td></td>
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<tr>
<td>Protection Operation tests</td>
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</tbody>
</table>
List of Tests

- Step response tests
- Control mode transfers
- Commutation failure tests
- Power/Current ramp tests
- AC and DC faults
List of Tests

- Auxiliary systems
- Reactive power control
- Generator/Last AC line tripping
- Dynamic Tests of Auxiliary controls
- Verification of replica
FACTORY TEST OBJECTIVES

- Verification of Controls and Protection
- Verification of PSCAD Study Results
- Verification of RTDS Replica
- Training of Engineering Personnel
- Training of Operating Personnel
The objective of the functional performance tests is to check proper operation of individual cubicles and correct interaction, functionality and interfacing of all components and subsystems.
**Parallel Factory System Tests (PFT)**

- **Converter transformer protection and cooling system**
- **Converter valves and Cooling system control and protection**
- **DC switchgear operation**
- **AC and DC filter protections**
- **Auxiliary supplies**
The vendor should provide a proposed list of tests to be performed at least 6 months before the start of tests.

The list is first reviewed by the owner.

Any concerns are discussed with the vendor.

List of tests is then finalized.

The tests that shall be repeated during site commissioning should be agreed upon at this time as well.
After the test list has been agreed, the vendor should provide description of each test.

First draft should be provided at least 4 months before the start of tests.

The description should include the following:

- Pre-conditions for the test
- Step by step test description
- Expected result
- Acceptance criteria
Review of Test Descriptions

- Details of each test should be reviewed
- Any concerns should be discussed with vendor
- The descriptions should then be changed to reflect the agreed changes.
- The list of tests that customer will witness is agreed at this stage.
The tests can be performed using any of the following methods:

- Using actual hardware and AC equivalents
- Using replica and AC equivalents
- Using PSCAD and AC equivalents

Some tests must be repeated by more than one method to verify the models.
It usually takes 3-4 months for the vendor to be ready for the actual FPT/DPT tests.

During this time the vendor sets up the cubicles and performs the tests without customer presence.

At the end, the software is finalized.

The customer is then invited to witness the tests (3-6 months)
CUSTOMER PARTICIPATION

The customer participation should be as following:
- System studies engineers
- Maintenance engineers
- Station and Control Center operators

The system studies engineers should be the one who were involved in system studies.

The maintenance engineers and operators should be the individuals who are assigned to actually maintain and operate the DC system.

The objective is to ensure that tests meet the requirements and to train the operators.
Test Approval Process

- The process should include the following:
  - The documentation to be provided to customer
  - Time for review and comments
  - Process for discussion of failed tests
  - Process for repetition of failed tests
  - Discussion of any control/protection changes.
  - Documentation of control/protection changes
FPT STEPS

PRE-COMMISSIONING SETUP

SUB SYSTEM TESTS

SYSTEM TESTS
Setup each cubicle
Check Power Supplies
Verify the all the hardware is included
Verify all the settings are correct
Power up the cubicle
# EQUIPMENT MODELS

<table>
<thead>
<tr>
<th>Icon</th>
<th>Description</th>
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<tbody>
<tr>
<td>🔄</td>
<td>AC sources (Infinite source)</td>
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<tr>
<td>✔️</td>
<td>Converter and AC filter breakers</td>
</tr>
<tr>
<td>🌐</td>
<td>DC switchgear, Electrode lines, DC line/cable</td>
</tr>
<tr>
<td>🚫</td>
<td>Converter valves, Converter transformers, Smoothing reactors</td>
</tr>
<tr>
<td>⚡️</td>
<td>AC &amp; DC filters</td>
</tr>
</tbody>
</table>
Sub System Tests

Check each cubicle for its functions

Check all signal outputs to other cubicles

Check all incoming signals from other cubicles
Factory System Tests

- Check operation of control and protection
- Operator controls
- Monitoring Systems
- The control and protection systems are connected to a simulator model
<table>
<thead>
<tr>
<th>Type of System Tests</th>
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<tbody>
<tr>
<td>Switching sequences</td>
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<tr>
<td>Reactive Power Control</td>
</tr>
<tr>
<td>Trip tests</td>
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<tr>
<td>System redundancy changeover</td>
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<tr>
<td>Operator Controls</td>
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<tr>
<td>Closed Loop Controls</td>
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</table>
• The purpose of Dynamic Performance Tests is to test the interaction between AC and DC systems as well as to verify the proper Pole control and DC protection behaviour under transient, dynamic and steady state conditions.
Using RTDS

Actual control hardware is used
DC system is modelled in RTDS
AC system equivalent is modelled in RTDS

Using PSCAD

HVDC Control and protection is modelled in PSCAD
DC system & AC System equivalents are modelled in PSCAD

Initially some tests are repeated both in RTDS and PSCAD to validate the PSCAD models.

This method allows the tests to be carried out simultaneously and reduces the number of tests on RTDS
All TFR, SER and HMI information is recorded during FPT/DPT tests so they could be used as reference during actual system tests.

The test configurations are chosen such that they can be repeated on the actual system.

The actual system configuration may vary slightly from FPT/DPT.
• The final documentation should include the following:

  • Test Description
  • TFR recordings
  • SER alarm listings
  • HMI screen shots
  • Plots of important system variables for PSCAD cases.
  • Explanation of any abnormal alarms.

• The FAT tests results are then used as benchmark for site commissioning tests that are repeated at site.
DURING PREPARATION OF LIST OF FACTORY TESTS, THE TESTS TO BE REPEATED DURING COMMISSIONING SHOULD BE IDENTIFIED AND AGREED UPON.

IT IS NOT NECESSARY TO REPEAT EVERY FACTORY TEST DURING COMMISSIONING.

THE RESULTS OF THE FACTORY TESTS DESIGNATED TO BE REPEATED DURING COMMISSIONING SHOULD BE USED FOR VERIFICATION OF COMMISSIONING RESULTS.

THE OPERATING STAFF SHOULD PERFORM THE SWITCHING OPERATIONS AS MUCH AS POSSIBLE.

COMMISSIONING TESTS SHOULD INCLUDE VERIFICATION OF ISOLATION AND RESTORATION OF EQUIPMENT FOR MAINTENANCE.
**ADDITIONAL TESTS FOR VSC**

<table>
<thead>
<tr>
<th>Test Description</th>
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<tbody>
<tr>
<td>Energization of the VSC converter and charging of valve capacitors.</td>
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<tr>
<td>Special VSC protections (e.g. PIR overload)</td>
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<tr>
<td>Reactive Power Control mode</td>
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<tr>
<td>AC Bus Voltage Control mode</td>
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<tr>
<td>Power Factor Control mode</td>
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<tr>
<td>Transfer between various control modes</td>
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<tr>
<td>STATCOM mode</td>
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<tr>
<td>Black start test</td>
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<tr>
<td>Energization and discharge of cable</td>
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</tbody>
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TRAINING
HVDC STATIONS GENERALLY TRANSMIT LARGE AMOUNT OF POWER

THE STAFF MUST BE PROPERLY TRAINED TO MINIMIZE THE OUTAGE TIME

TRAINING MUST BE TAILORED TO THE STAFF FUNCTION
TRAINING PROCESS

• AT THE BEGINNING OF THE PROJECT IDENTIFY THE ENGINEERING, OPERATIONS AND MAINTENANCE STAFF THAT WILL BE RESPONSIBLE FOR THE HVDC SYSTEM

• ENGINEERING STAFF SHOULD PARTICIPATE IN ALL FACTORY TESTS AND THE SYSTEM TESTS DURING COMMISSIONING

• OPERATING STAFF SHOULD PARTICIPATE IN FACTORY TESTS AND COMMISSIONING OF THE EQUIPMENT ON SITE.

• A COMPREHENSIVE CLASSROOM TRAINING SHOULD BE PROVIDED BY THE SUPPLIER’S SPECIALISTS BEFORE THE COMMISSIONING STARTS.
TRAINING PROCESS

• ALL HANDS-ON DEMONSTRATIONS AND LECTURES SHOULD BE VIDEO RECORDED.

• A TRAINING SIMULATOR (REPLICA) SHOULD BE PROVIDED FOR THE OPERATORS.

• SIMULATOR SHOULD BE ABLE TO DUPLICATE NORMAL AND FAULT CONDITIONS.

• A REAL TIME DIGITAL SIMULATOR (RTDS) REPLICA OF THE HVDC CONTROLS SHOULD BE PROVIDED FOR THE ENGINEERING STAFF
At least two operators from each station should participate in the FACTORY testing. The operators will perform switching operations.

Familiarize with TFR and SER recordings.

Familiarize with HMI screens.

Familiarize with reactive power control.

Familiarize with protection operations and reset process.

Familiarize with active power control.

Familiarize with current control mode.

Familiarize with clearance procedure for maintenance.
Engineers from System studies, Maintenance and Operating departments should participate

Engineers will learn everything the operators will learn

Details of control and protection systems

How to analyze Transient fault recordings

How to use SER recordings for fault analysis

How to identify faulty equipment

How to restore HVDC system after converter tripping

How make control and protection setting changes
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