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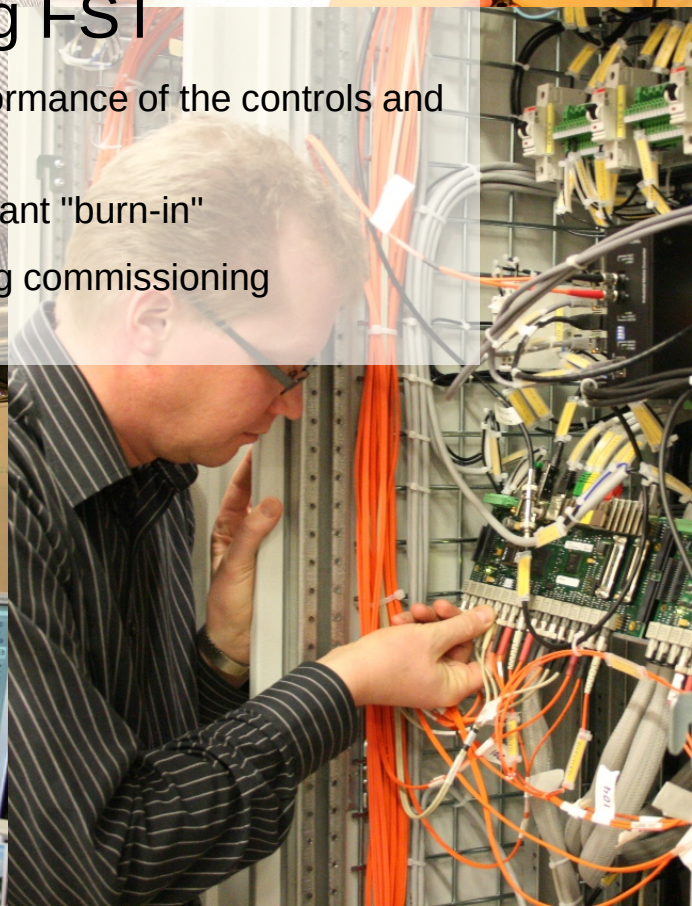
ABB Experiences
RTDS Simulations

Contents

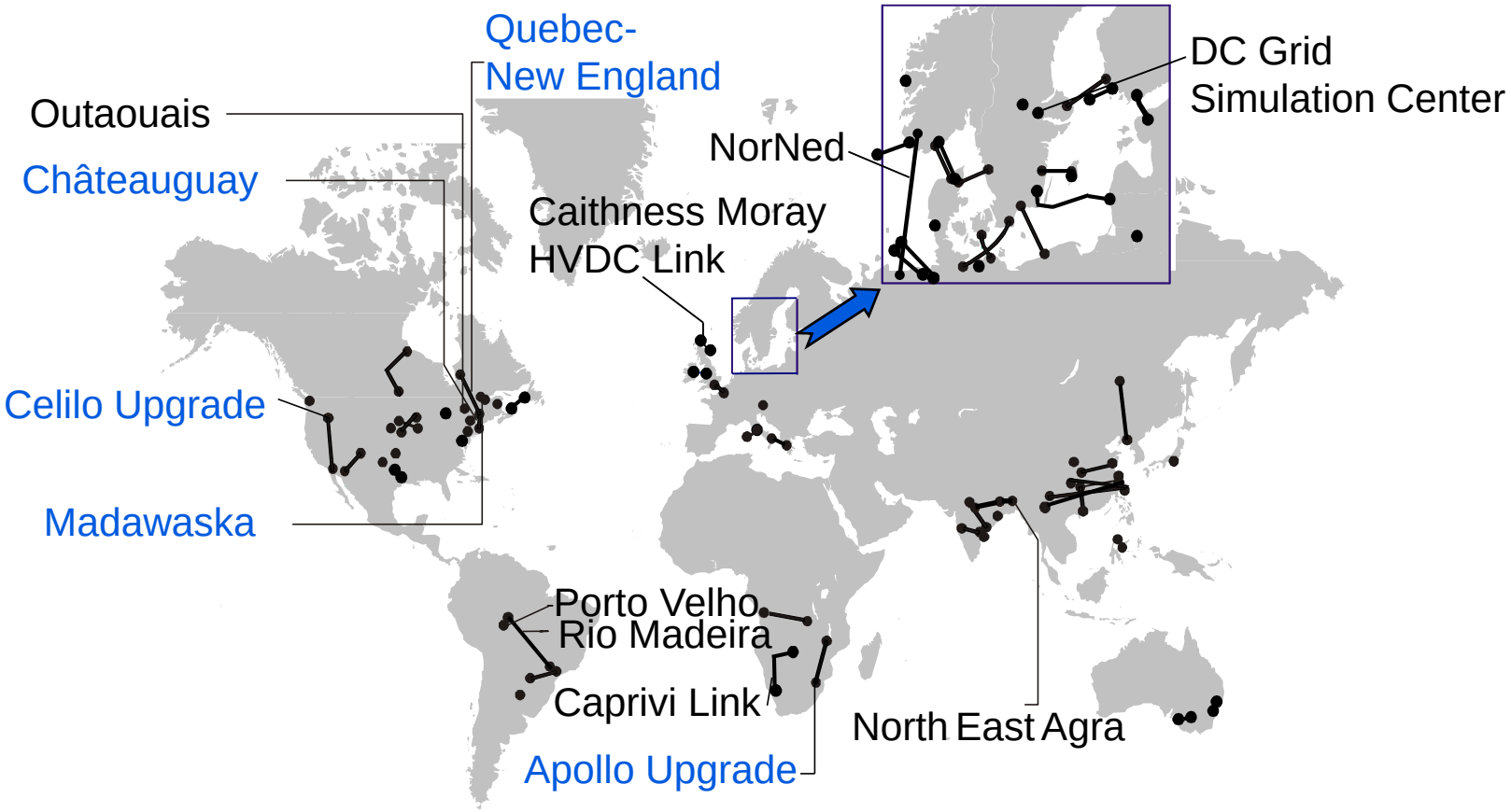
- Factory system testing (FST)
- Interface between RTDS and control
- IO requirement, an example
- MMC Interface
- FST Performance and achievements
- Experience with real time simulations
- DPS Vs. FST
- How far are we from reality?

Factory System Testing FST

- Systematic testing and verification of the functional performance of the controls and protections.
- Shorten the time for commissioning and plant "burn-in"
- Minimize disturbances to the AC-system during commissioning



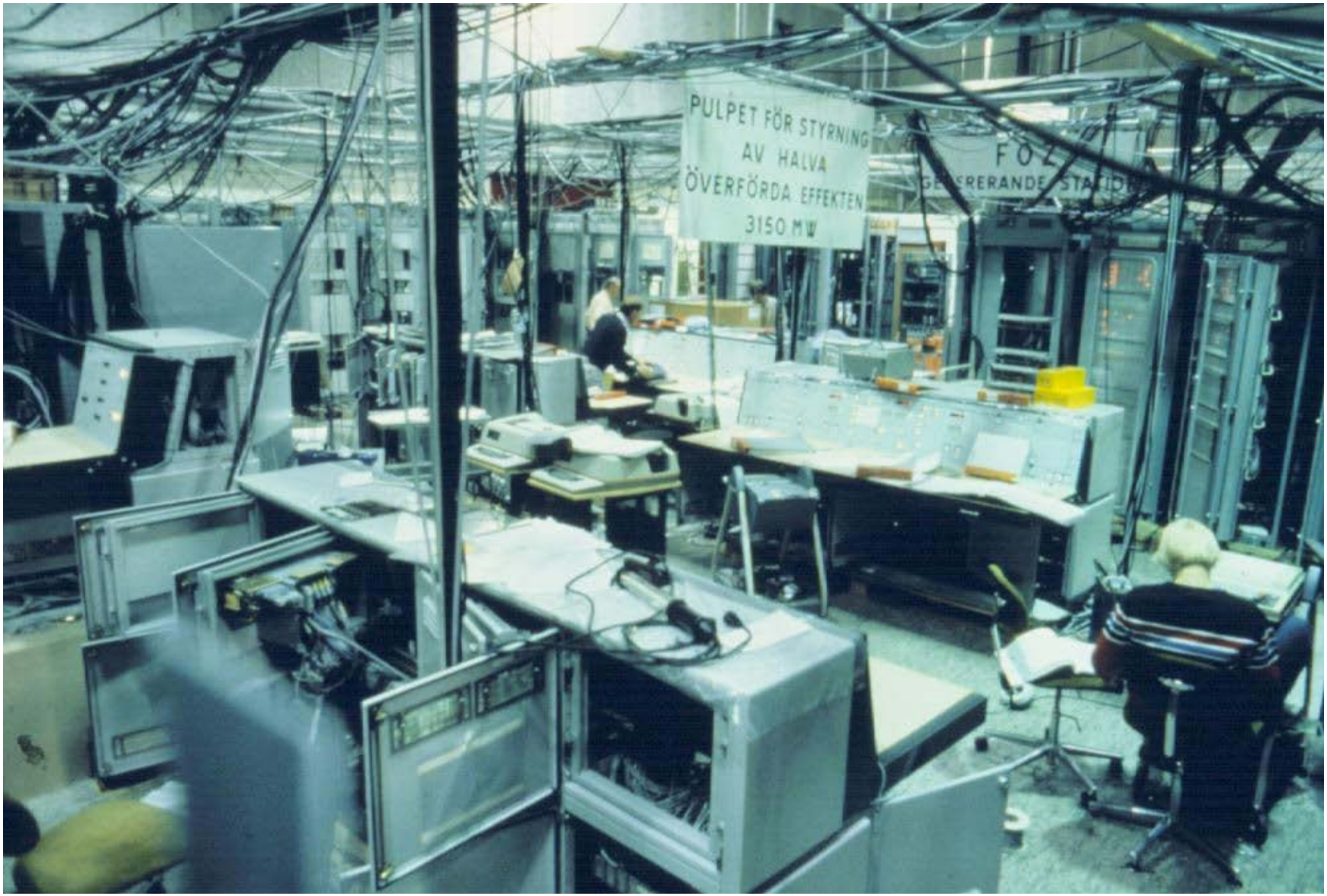
Experience with real time simulation
FST and replicas



80+ FST
6 HVDC Classic replicas
5 HVDC Upgrades replicas
3 HVDC Light Projects

HVDC simulators for Factory System Test (FST)

- First HVDC delivery was Gotland 1954.
- The first FST was for the Itaipu project, 6300MW 1980’s.
- First RTDS to Ludvika early 1990’s
- Regular use of RTDS since 2004



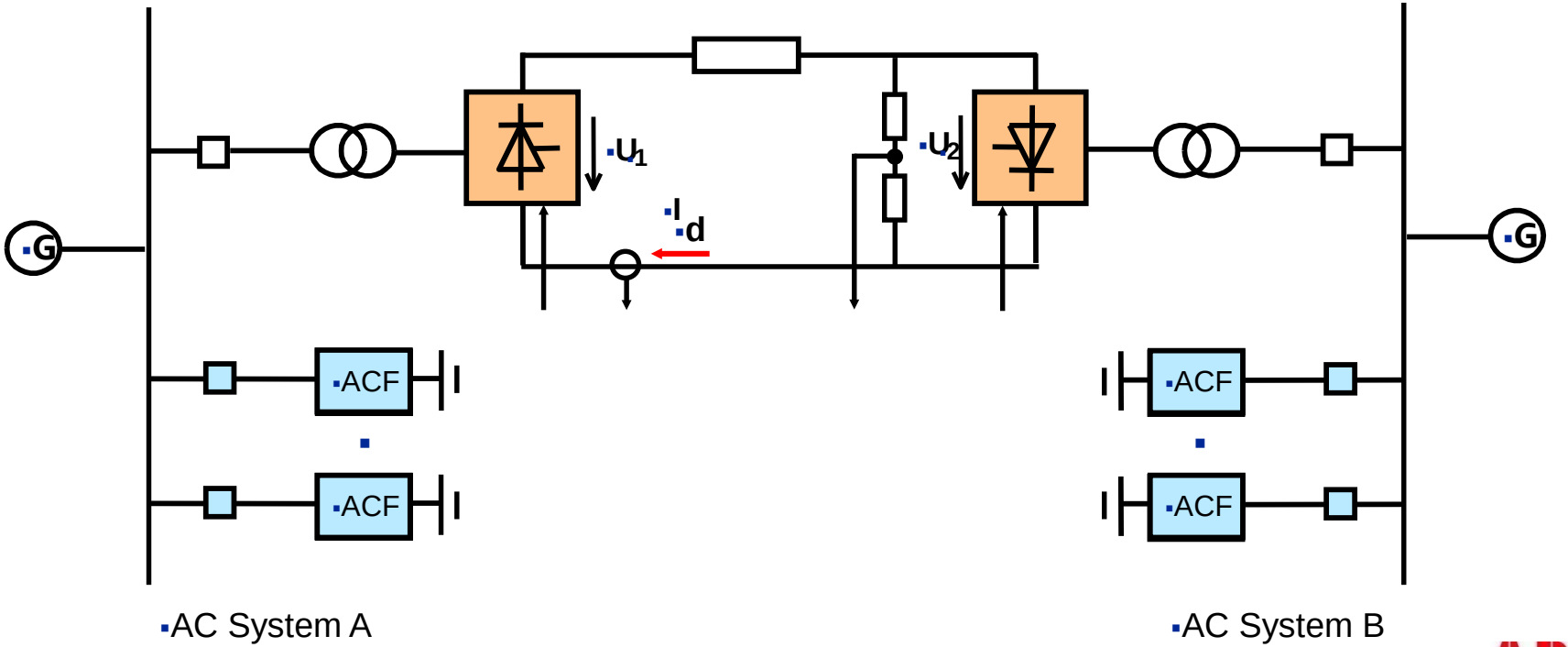
- Itaipu 6300MW

FST room layout

FST

What is an FST simulator?

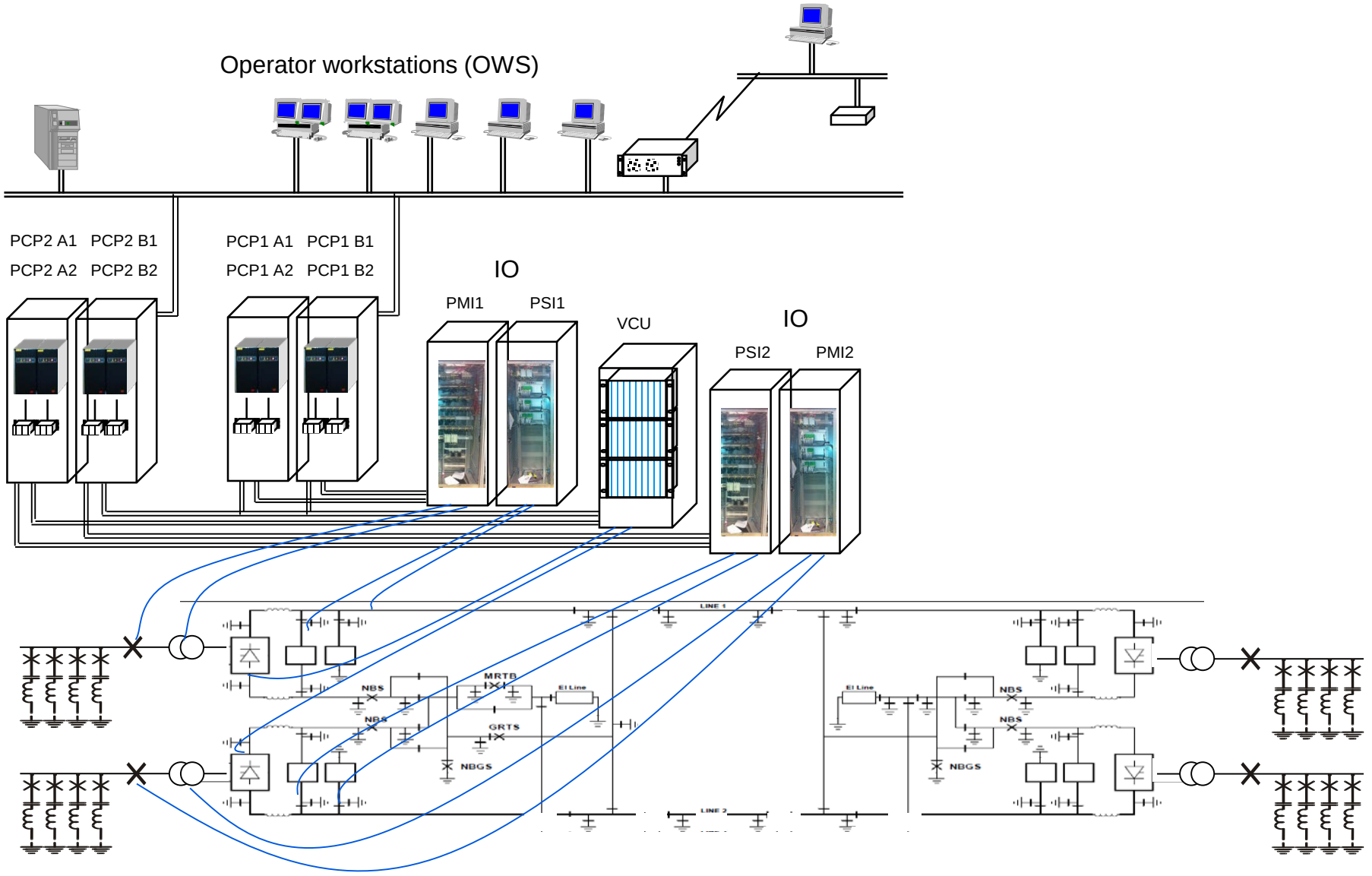
- Representation of main circuit equipment. Equipment that is important for testing software functions is included.
- Correct scaling of measurements. From terminal blocks to control.
- FST is a functional test of software and hardware for control and protection system. It is not a verification of performance of the HVDC transmission. So a simplified representation of customers network is used.



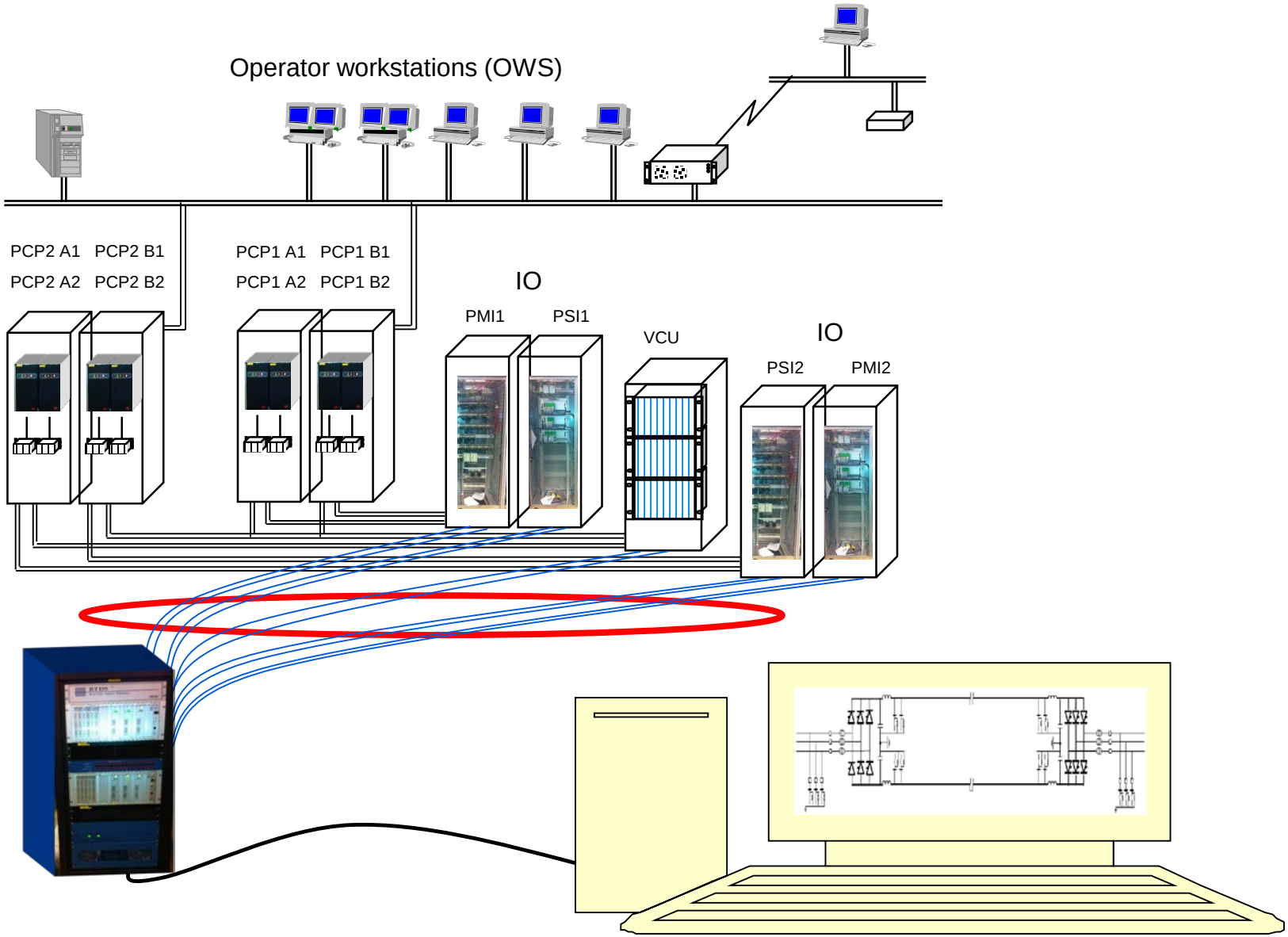
What is an analogue FST simulator?

- Scaled model of the plant based on 40V dc, 200mA dc, 10V ac.
- Generator was exchanged for a digital model instead of analogue model.
- Loss compensation was added at various positions, important for the valve and converter transformer.

HVDC Transmission



FST


Operator workstations (OWS)
PCP2 A1
PCP2 B1
PCP2 A2
PCP2 B2
PCP1 A1
PCP1 B1
PCP1 A2
PCP1 B2
IO
PMI1
PSI1
VCU
IO
PSI2
PMI2

Interfaces between RTDS and controller

The goal is to test the controls with delivery interfaces.

Classic

- Voltage amplifiers
- Current amplifiers
- Optical firing input (replaces gate unit of thyristors)
- Electrical firing input (replace Valve Control Unit)
- Optical current transducers

Light

- Low voltage inputs to control system for voltages and currents
- Optical firing input (replaces gate unit of IGBT)
- FPGA interface for special models (motor interface, shaft sensors)
- Optical current transducers

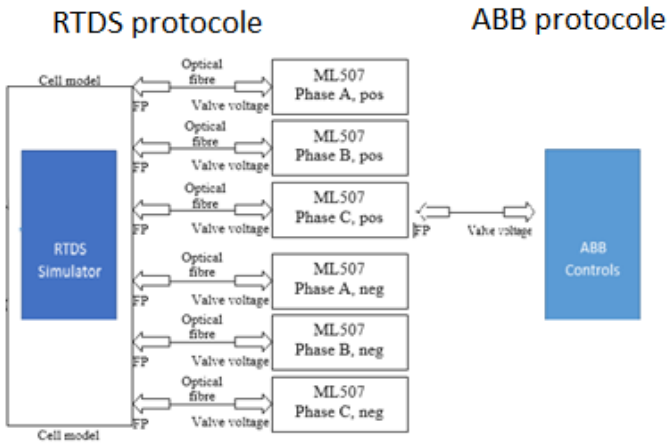
- For both light and classic valves are single entities

Examples of IO requirements

- Scaling of measurements. From terminal blocks to controls.
- An example from a recent bipole multi terminal classic project
- Run on three racks of RTDS.
- 243 analog out channels from the RTDS GTAO units.
  - 144 current amplifiers
  - 58 optical current measure units (remote units)
  - 60 low voltage measurement interfaces
- 127 switchable interfaces (circuit breaker, high speed switch and disconnector)
- 16 - 6 pulse valve groups
  - 96 optical firing interfaces
  - 96 electrical firing interfaces
- 8 tap changers

Modular Multilevel Converter interface:

1. FPGA interface to use RTDS protocol on one side and HVDC protocol on the other



2. Significant number of cells units(Modular Multilevel Converters), MMC units (cell voltage calculations outside RTDS)

- HVDC Bipole in one RTDS rack

80+ HVDC FST performed with RTDS

Classic HVDC and LCC

- XS800 3000MW/±500kV
- Skagerrak 1 & 2 upgrade 500MW/ /±250kV
- Sharyland I 150MW//±21kV
- NordNed 700MW/±450kV
- Outaouais 1250MW/175kV
- Chateauguay 2x500MW/140kV
- Blackwater 200MW/57kV
- IPP Upgrade 2400MW/±500kV
- Sapei 1000MW/±500kV
- Fennoskan 2 800MW/500kV
- Apollo upgrade
- Highgate 200MW/120kV
- Fennoskan 1 upgrade 500MW/400kV
- Inga Kolwezi 560MW/ /±500kV
- Railroad DC Tie 150MW/±21kV
- Rio Madeira Bip 3150MW/ /±600kV
- Rio Madeira BtB 2x400MW CCC
- Oklaunion 220MW/ /±31kV
- Eel River upgrade 350MW/80kV
- Skagerrak 3 upgrade 4410MW/350kV
- LitPol BtB 500MW/ /±70kV
- North East Agra 6000MW/ /±800kV (multi terminal)
- HQ-NG Upgrade 2000MW/ /±450kV (multi terminal)
- Celilo PDCI Upgrade 3800MW/ /±500kV

VSC HVDC light

- Caprivi link, 300MW/350kV
- Nord Eon 1, 400MW/ /±150kV
- EWIP, 500MW /±200kV
- DC Grids
- DolWin 1, 800MW /±320kV
- Mackinac, 200MW/71kV
- Skagerrak 4, 715MW/500kV
- DolWin 2, 900MW/±320kV
- Troll 3 & 4, 2*50MW /±60kV
- Åland, 100MW/±80kV
- Direct link, 60MW/ /±80kV
- Nordbalt, 700MW /±300kV

Highlights and comments

- 4 winding transformers
- Bipole and CCC back to back together
- Combined classic and light converters in bipole configuration
- Successful upgrade to RTDS racks without any incidents. Exchange of backplane and cards (3PC->RPC->GPC>PB5)
- Supply of replicas (controls + simulator).
- 24 hour operation, 7 days a week, 52 weeks a year of simulator and controls.

- Customers are demanding larger AC equivalents for FST, which does not add any real advantage. To include an AC equivalent there must be specific tests requiring an equivalent, such as control functions for an identified condition in the network such as SSTI or black start. Other tools have ability to include more detailed models of the AC network.
- FST is mainly about showing that the control system is stable, protections are coordinated, protections have correct actions, switch overs, ramps and control functions are working correctly. FST is not a dynamic performance study, it is a function performance verification of the control system. At an FST, time is critical and the test setup must work satisfactorily.

Experience with real time simulation

DPS verses FST

- PSCAD is free from physical limitations.
- Can use frequency dependent lines on a larger scale, non linear models and interpolation is possible in PSCAD.
- PSCAD for DPS
- Accurate models of all plant

- Real time simulation for FST.
- FST is about protection coordination.
- Switchover and fail safe operation, sequences, HMI, TFR, burn in.
- Focus on complete C&P system.
- Training of operators.
- Time is critical to avoid delays.
- Typical performance of plant external to HVDC is more accepted.

Experience with real time simulation

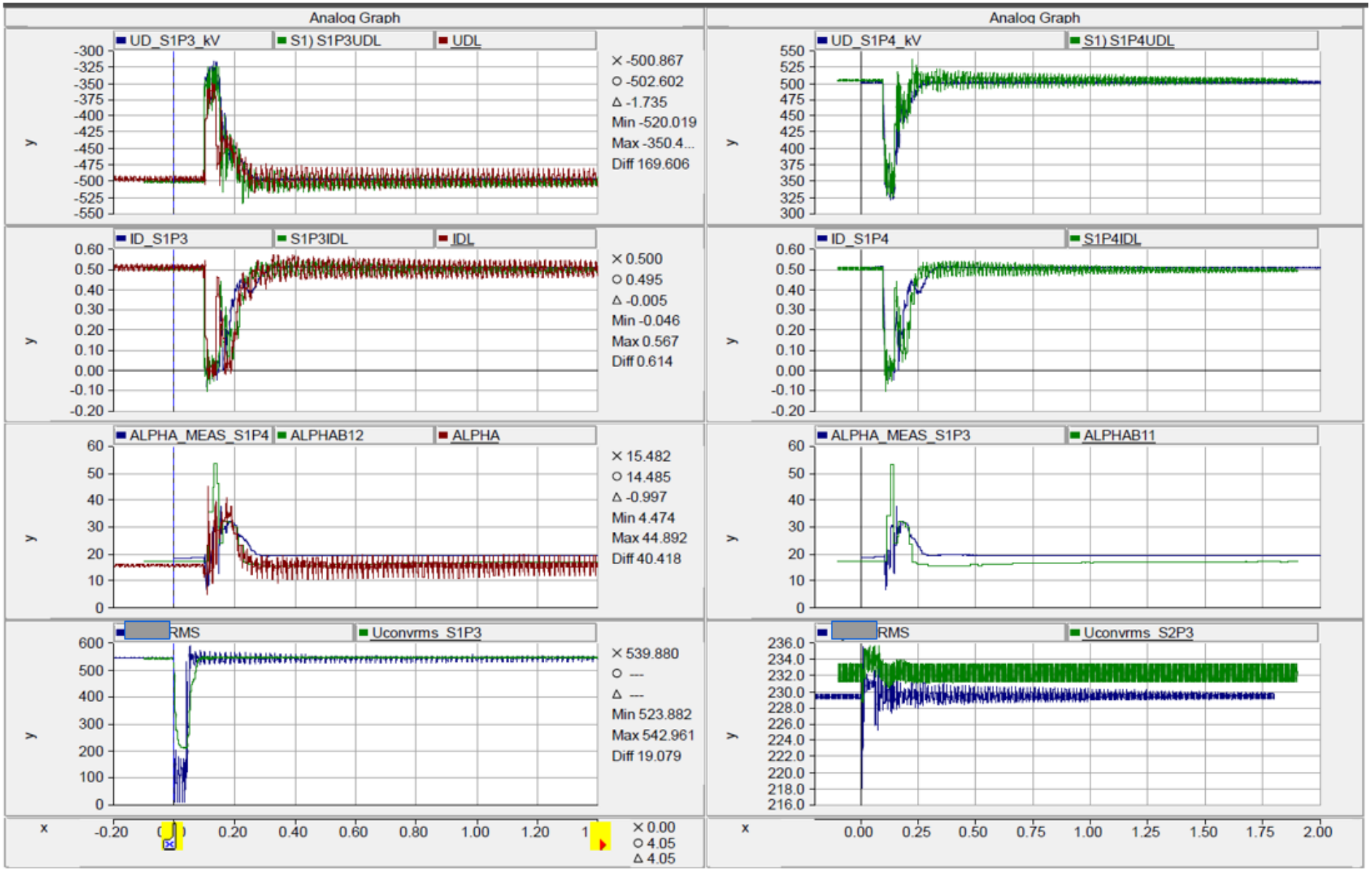
Real time = Real life?

- Non-linear components in real time require simplifications.
- Multi processor power is used to calculate different parts of the network in parallel.
- Real time simulation is about dividing up the components of the simulation to the hardware available and making it work.
- Natural points of separation can be used to split up a simulation.
- Decoupling elements are used where this is not possible.

Experience with real time simulation
Real time = Real life?

- Digital simulation increases options and complexities.
- Over belief in real time simulation with external controls.
- Clear purpose for the simulation and requirements for performance need to be defined.
- Real time simulation is a tool to test/validate specific functionality/functions.

How far are we from reality?



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