Simulation temps réel – Projet Twenties

X. Guillaud – F. Colas
OUTLINE

• Real-Time simulation through the ages
• Brief presentation of Twenties Project
• Role a Multi Terminal DC grid real-time mock_up
• Use of the real time simulation for the design of the mock up
AIM OF THE PRESENTATION

The aim of the presentation is to present the capability of the real-time simulation in the context of the Twenties project more than the presentation of the Twenties project itself.
REAL TIME SIMULATION
« THROUGH THE AGES »
REAL TIME SIMULATION THROUGH THE AGES

1960
1970
1980
1990
2000

Year

Analog Simulators

Custom, Complex, Costly, Closed

Hybrid (Analog/Digital) Simulators

Digital Supercomputer Simulators

Digital Custom Simulators

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REAL TIME SIMULATION THROUGH THE AGES

Classical Power System

Thyristor applications

Power converter for electrical machine applications

Power converter for power system

Hybrid vehicle Embedded grid

Renewable energy Micro-Grids

TYPICAL APPLICATION:
Test of thyristor converter controllers

Real Time simulation (50 μs, 100 μs)

Interpolation method may be needed to be more accurate on the thyristor impulse time
NEW APPLICATION: Test of transistor converter controllers

Instantaneous Modeling of the converter (< 1μs)

Real Time Modeling (50μs 100μs)
NEW FORM OF HYBRID SIMULATION
Power Hardware in the loop

Real-Time Simulator

Bus Voltage

Current Injector

ADC

DAC

v1 v2 v3

i1 i2 i3

15 kVA
10 kHz Bandwidth
Power Amplifier

Real system
Ex: PV System

Real-Time Simulator

Poste de travail PC
BRIEF PRESENTATION

OF TWENTIES PROJECT
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**ORGANISATION OF TWENTIES PROJECT**

**WP1: Project Management (REE)**

**WP2: Specification and requirements for the demonstrations (REE)**

- Barriers to be overcome
  - KPI definition and measurements
  - Detailed requirements and specifications for the demonstrations

**Task Force 1:** Contributions from intermittent generation and load to system services

- Demo IBD
  - WP3 R&D
  - WP9 Demo
- Demo DONG
  - WP4 R&D
  - WP10 Demo

**Task Force 2:** Allow for offshore wind development

- Demo RTE
  - WP5 R&D
  - WP11 Demo
- Demo ENDK
  - WP6 R&D
  - WP12 Demo

**Task Force 3:** Give more flexibility to the transmission grid

- Demo ELIA
  - WP7 R&D
  - WP13 Demo
- Demo REE
  - WP8 R&D
  - WP14 Demo

**WP15 Economic impacts of the demonstrations, barriers towards scaling up and solutions (IIT Comillas)**

**WP16 EU-wide integrated assessment of the demonstration replication potential (RISOE)**

**WP17: Dissemination (REE)**
DEMO 3 Objectives

- To provide the critical building blocks of DC grid control
- To define protection strategies and demonstrate the viability of DC breakers

DEMO 3 organisation

Two main Work packages
- WP 5 (R&D)
- WP11 (demonstration)
Mains studies performed within WP5

- Comparison of the performances of different converters topologies
- Comparison of radial, multi-terminal, meshed topologies
- Impact of AC faults on the DC grid
- Protection coordination and special protection schemes
- Ancillary Services functions
- Fault ride through capability
- Economic analysis in regards to market integration
- Reliability analysis
ROLE OF A REAL TIME MOCK-UP
THE STUDIED SYSTEM: Multi Terminal High Voltage DC grid

Interaction with AC system

Meshed grid

Antenna connection

GSC: Grid Side Converter
WFC: Wind Farm Converter

Onshore

Offshore
2 AIMS OF THE STUDY

Management of the DC voltage level and the power flow in the grid (Pierre Rault, Phd student in L2EP)

Fault Selective detection (Justine Descloux, Phd student in G2ELAB)

Most of the studies have been achieved with EMTP but we wanted to have experimental validation.
Limitations of the mock up
- Influence of resistivity of the cables
- High dynamic behavior of low voltage cable is not the same as for high voltage cable

Interest of the Mock-up
- Intermediary step between full simulation and demonstrator
- Experimental validation of the behaviour found in simulation
- More realistic validation of the communication between the different elements
- Test of the instrumentation for the fault detection
REAL-TIME SIMULATION AND THE MOCK-UP
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General overview

Real-time simulator
Sample time $\Delta T$: 10-20 $\mu$s

FPGA for a virtual VSC
Sample time $\Delta T$: 100-200 ns

AC Grid real-time simulation

DC Breaker
And protection algorithms

Protection algorithm

Virtual VSC

Power Amplifier

VSC

Virtual DC

Virtual AC

Vdc

Idc$\text{nom}$

Vdc = 250V, Idc$\text{nom}$ = 10A

Uac = 125V

AC Grid And Windfarms simulation

Wind farms
Real-time simulation

RT simulated VSC

Real VSC

Vdc

Idc

Vdc

Idc

Low voltage DC Grid

2x15 km of cables

DC Experimental grid

IEC 61850 Network

Communication Link

DC breaker

DC Supervisory Control And Data Acquisition (SCADA) system

General Supervisor

On/Off DC breaker

Nexans cables

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Vdc = 250V, \( I_{dc\,nom} = 10A \)

Uac = 125V
Inverter Structure
- Classical 2 levels VSC
- LCL filter stage for AC side
- Nominal apparent power: 3000VA
Vdc = 250V, \( I_{dc{}^{\text{nom}}} \) = 10A
Uac = 125V

RT simulated VSC
Inverter design – Simulated VSC

25/50 μs real-time simulated AC grid

Classical multi core CPU

Power Circuit

DC Bus

DC

250V

3000W

125V

FPGA, time step = 270ns

To low voltage DC Grid
Vdc = 250V, \( I_{dc\,nom} = 10\)A
Uac = 125V
Inverter design – Real VSC

High level control:
- Gateway to the SCADA system
- Initialization sequence

Low level control:
- Voltage and current loops
- PWM generation
- Over current and voltage software protection
Use of real time simulation to design and test the real VSC Control algorithm

FPGA RT model

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Inverter design – Real VSC
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Inverter design – Real VSC

3 Operating Modes:
1- Slave Mode
2- Master Mode
3- Droop Mode

✓ Totally homemade and remote control
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Inverter design – Real VSC
Vdc = 250V, Idc_{nom} = 10A
Uac = 125V
Kundur power system

- 2 areas
- Primary frequency and voltage control
- Each group has a PSS

Simulated in Real Time
Time step = 25µs
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Simulated AC Grid

Hybrid simulation

Time step = 25µs
Simulated Windfarms

Station 3 and 4 modeled as a power control Station

Station 5 is in Slave mode (Power controlled)

Power production for Stations 3, 4 and 5
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General overview

V_{dc} = 250V, I_{dc}^{nom} = 10A
U_{ac} = 125V

SCADA system
Objectives:

- Control each station
- Send references to the local control of each station
- Coordinated control
- Control the state of each component

=> Act as the DC grid dispatching
All components are remote controlled with a SCADA system.

**Communication Protocol**
- OPC
- Modbus TCP/IP

**Perpectives**
Use only IEC 61850
\[ V_{dc} = 250V, \quad I_{dc}^{\text{nom}} = 10A \]

\[ U_{ac} = 125V \]

- Installed at 2 points
Large variation of power on the DC grid.
Test on the droop voltage capabilities
- Approximately 1.5 year of development
  - 2 PhD students (J. Descloux (G2ELAB Grenoble, P. Rault L2EP Lille)
  - 3 engineers (S-A. Amamra, H. Fakham, F. Colas)
  - 2 Professors (B. Raison, X. Guillaud)
  - Support from RTE-France and Twenties project
• We have presented the real-time simulation in the context of Twenties project but the applications of real-time simulation are much wider.
• For the of this mock-up, real-time simulation has been widely used either for the development or in the mock-up it self (Power Hardware in the loop)
• The future :
  – Improving the simulation model of the wind farms
  – Participation of the MTDC to the grid frequency regulation
  – Including new types of converter (ex : MMC)
Thanks for your attention