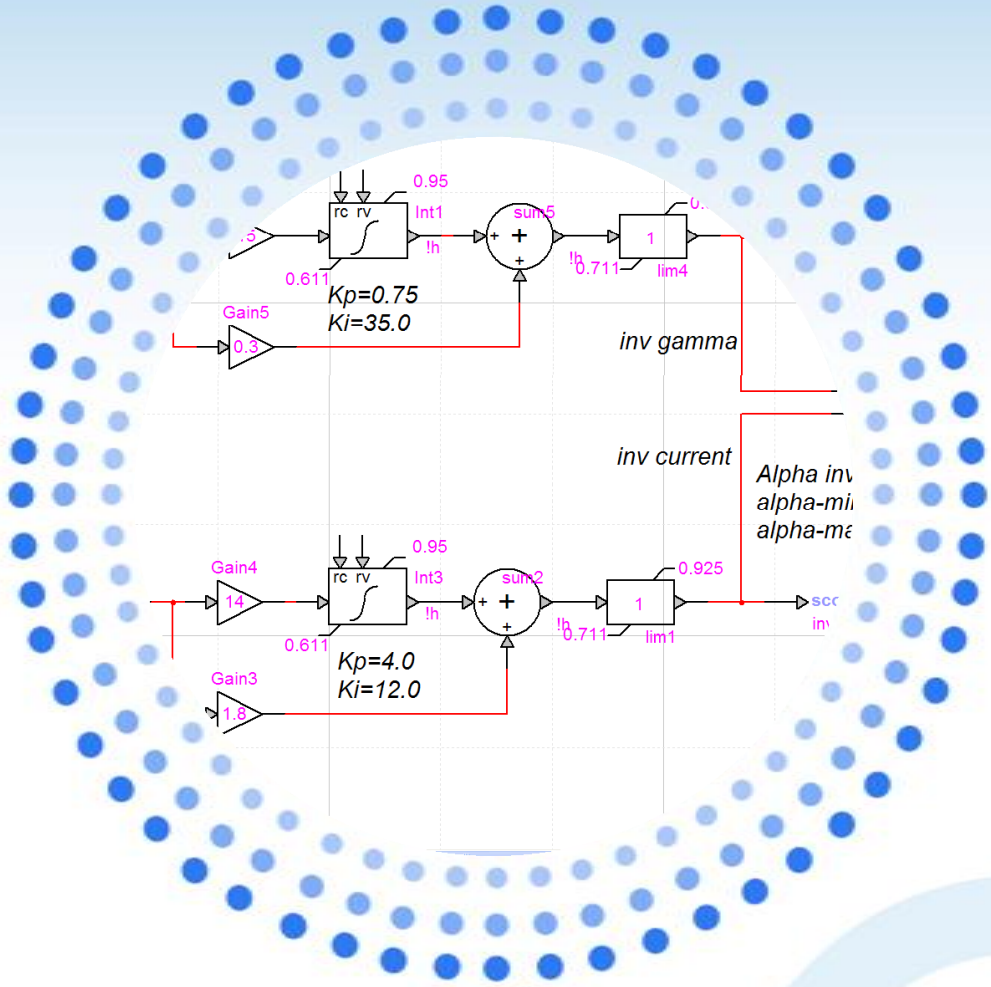


HVDC models in EMTP-RV

Sébastien Dennetière, EDF R&D, April 30th 2009

Presentation layout

- Why do we develop HVDC models ?
- Description of a detailed HVDC model in EMTP-RV
- Simulation results
- Description of an average HVDC-VSC model in EMTP-RV
- Simulation results
- Next developments

Why do we develop HVDC models ?

- Growing interest in HVDC links in transmission system
  - Avoid overhead lines construction
  - Flexibility

- HVDC links models are required :
  - Determination of the best HVDC solution in a specific case
  - Training of power system engineers

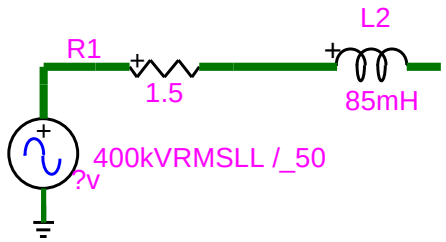
- 4 Models :
  - Detailed models for transient studies: generic & specific
  - Average models for system studies : generic & specific

Detailed HVDC model

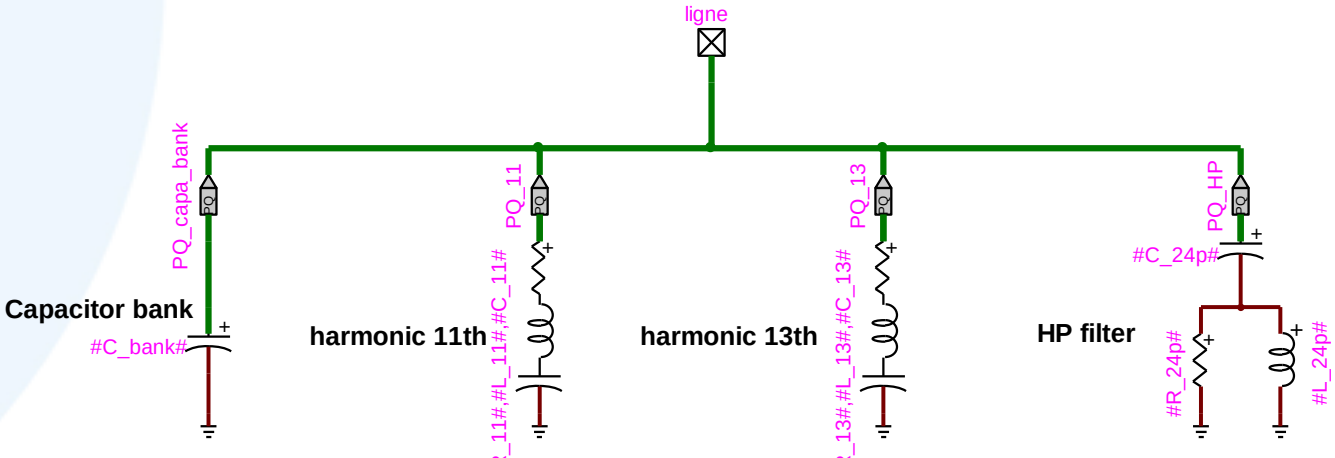
- Main characteristics :
  - Generic standard HVDC (Bipolar 12 pulses)
  - Rated power : 1200 MVA
  - DC voltage : +/- 500 kV
  - DC cable 1400 mm², 70 km
  - AC Filters : 11^{th}, 15^{th}, $23^{rd}/25^{th}$; DC Filters : 6^{th} & 12^{th}
  - Reactive power compensation : filters + capacitor bank
  - Smoothing reactor : 370 mH
  - AC Short Circuit Power : 6000 MVA
  - Control system :
    - Current controller on rectifier side
    - Gamma controller or current controller on rectifier side
- Developed by : University of Ontario Institute of Technology , Ecole Polytechnique de Montreal and EDF R&D

Detailed HVDC model

- AC network :
  - SCP = 6000 MVA

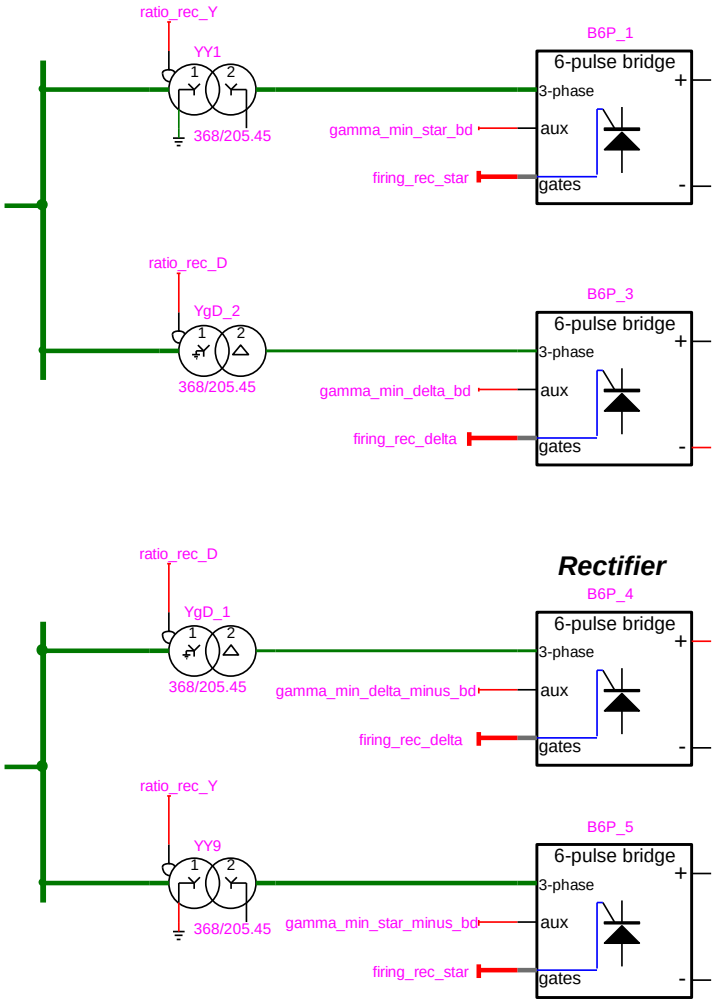


  - AC filters:
    - Each filter and capacitor bank generate ¼ of reactive power consumed by converters
    - Filters parameters are calculated from analytical expressions included into scripts



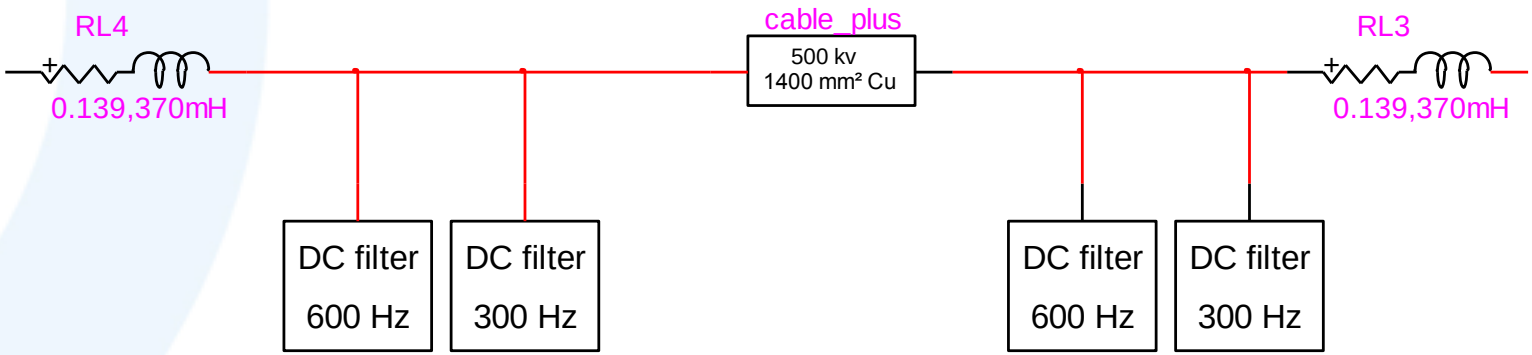
Detailed HVDC model

- Converters transformers :
  - Sn = 300 MVA / transformer
  - Tap changer
  - Xlf = 12.5%
- Converters :
  - 12 pulses
  - RC snubbers



Detailed HVDC model

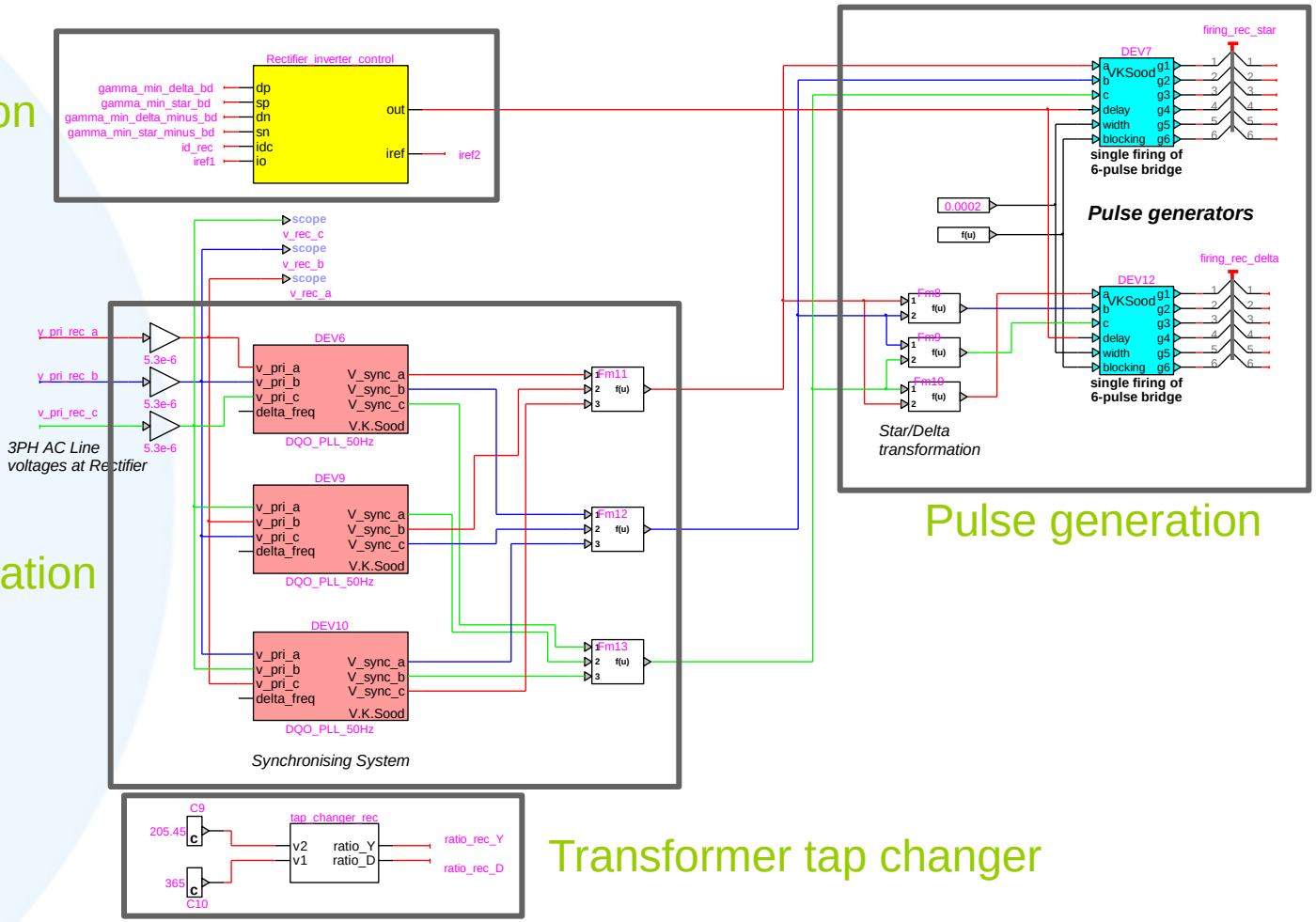
- DC Cables :
  - Paper insulated +/- 500 kV, 1400 mm²
  - CP model
- DC filters : RLC branches (6th et 12th)
- Smoothing reactance : 370 mH



Detailed HVDC model

- Rectifier / inverter control system

Regulation



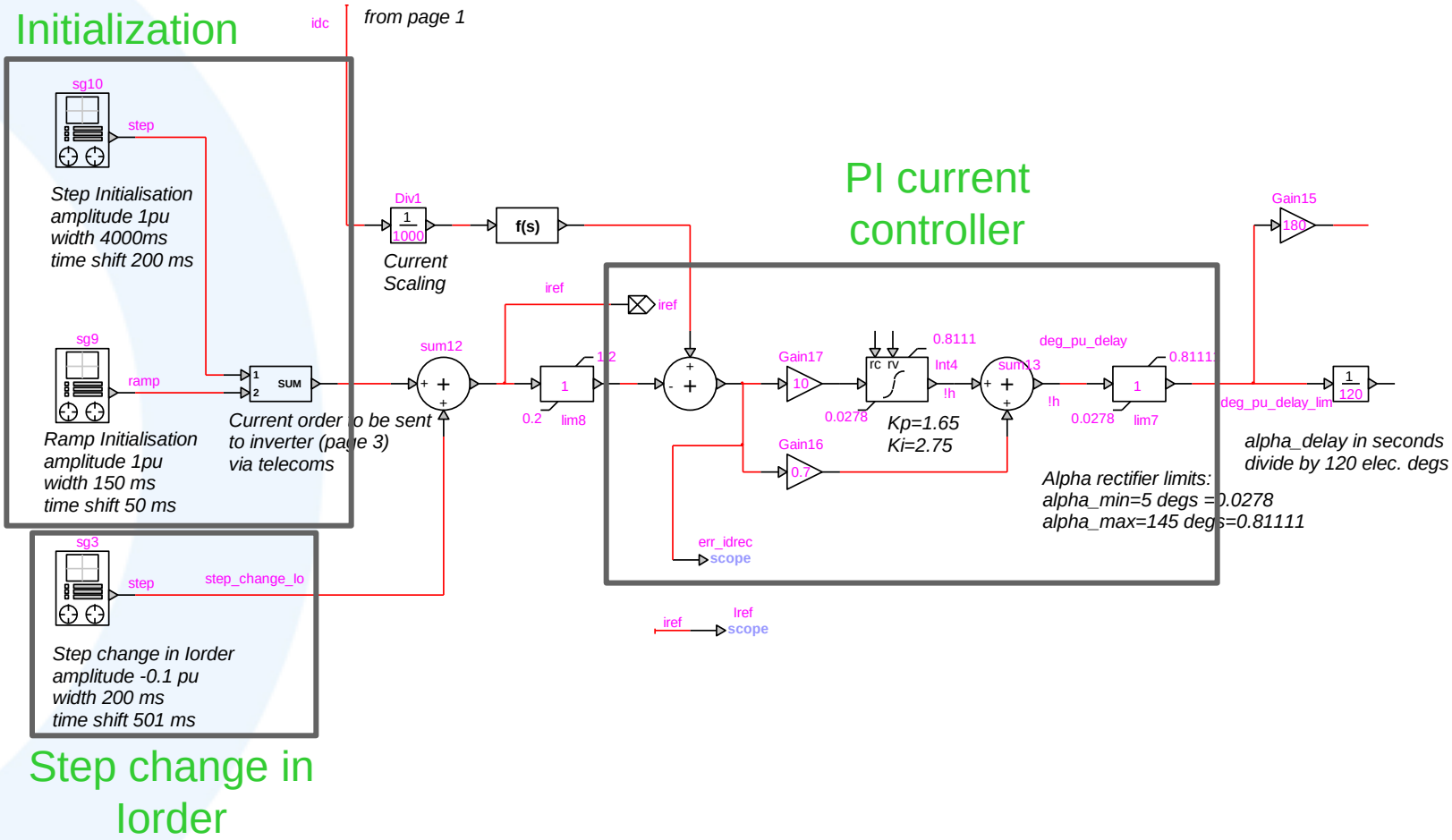
Synchronization

Pulse generation

Transformer tap changer

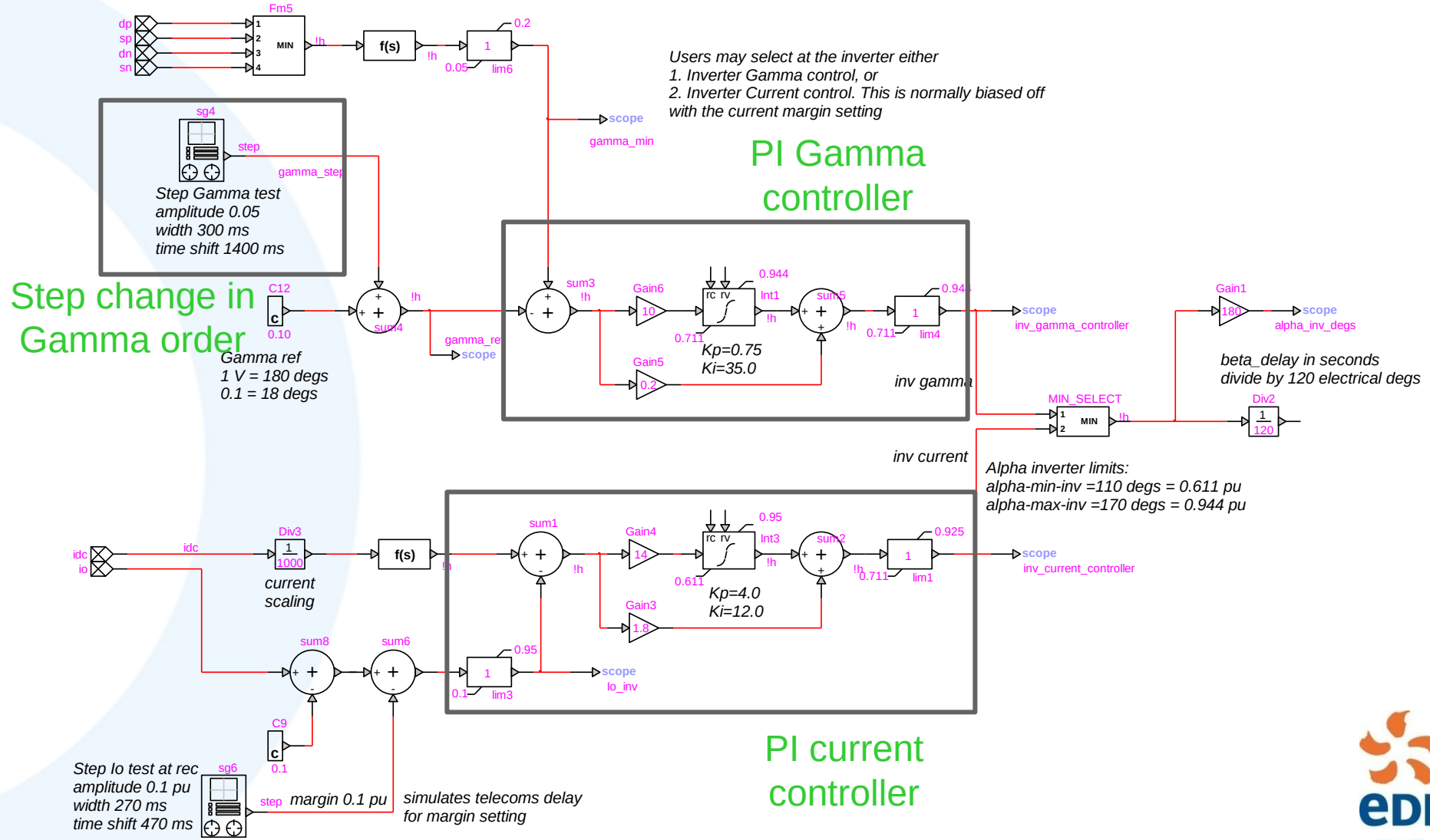
Detailed HVDC model

- Rectifier control system



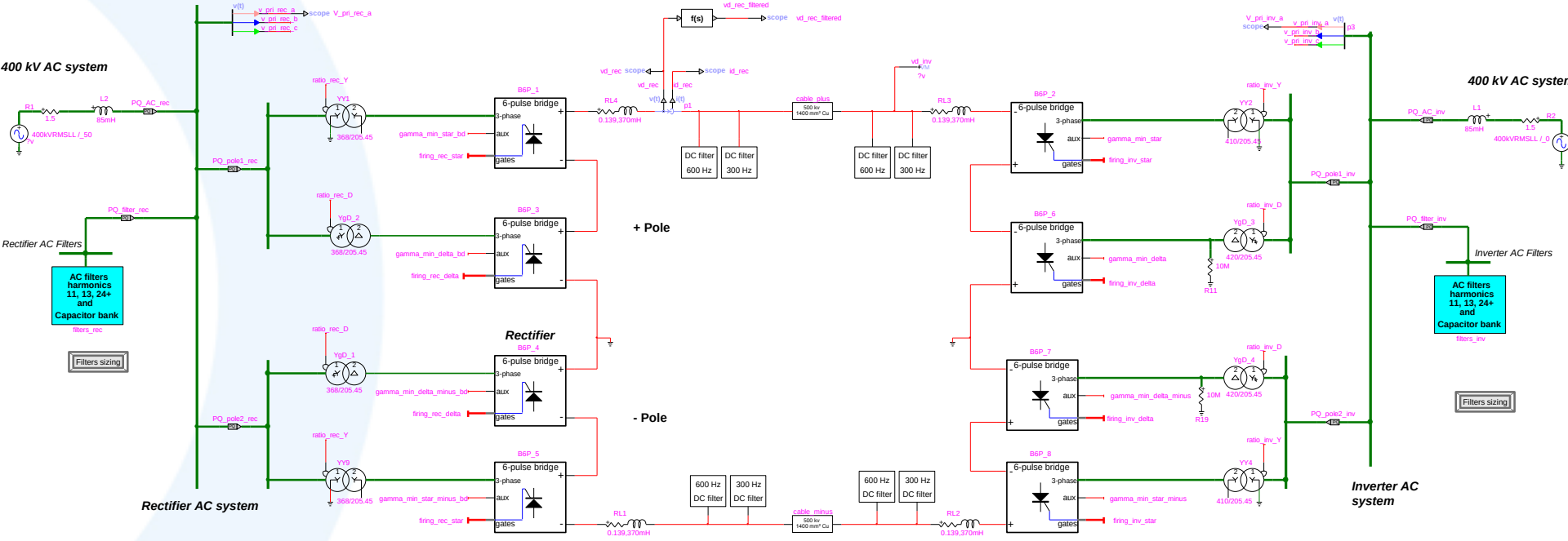
Detailed HVDC model

- Inverter control system



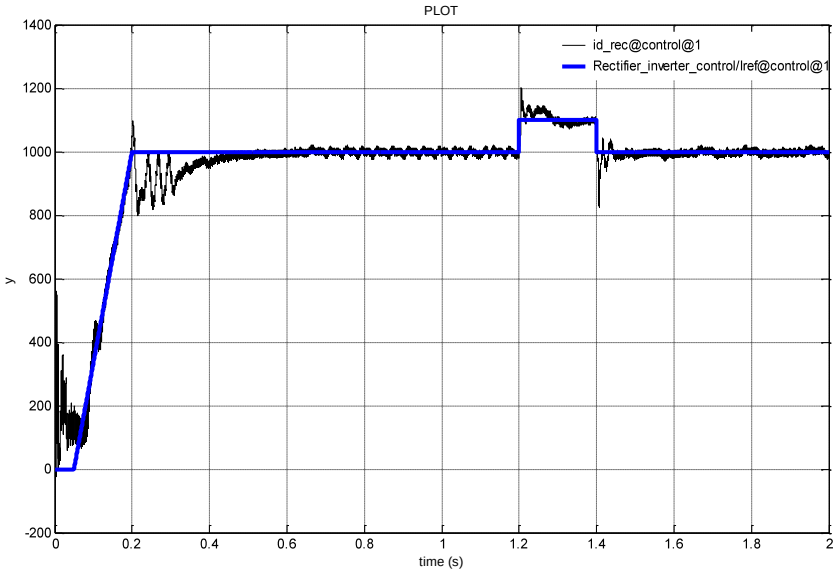
Detailed HVDC model

EMTP-RV design

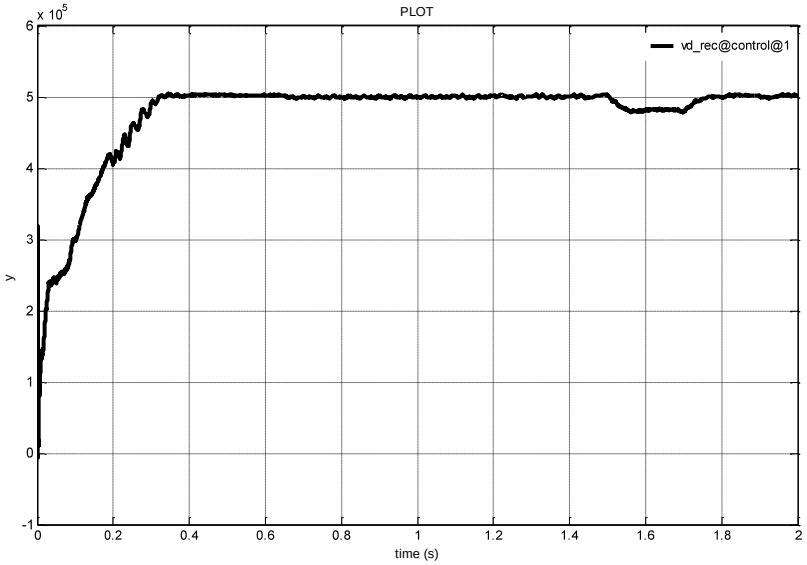


Detailed HVDC model

Simulation results



Step change in Iorder



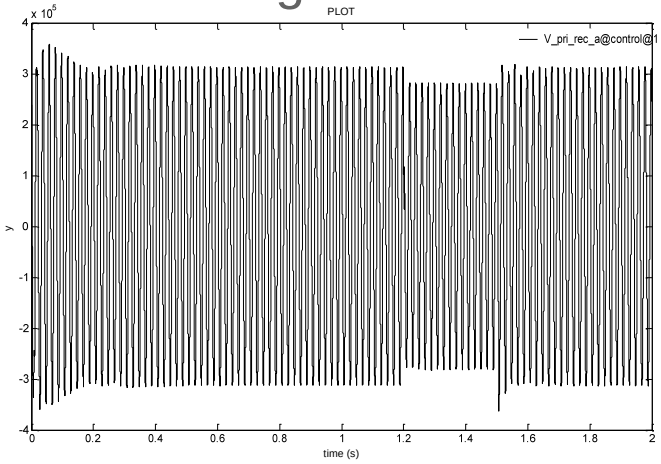
Step change in Gamma order

Simulation options : $\Delta t = 25\mu s$, $t_{max} = 2s$, CPU time = 30s

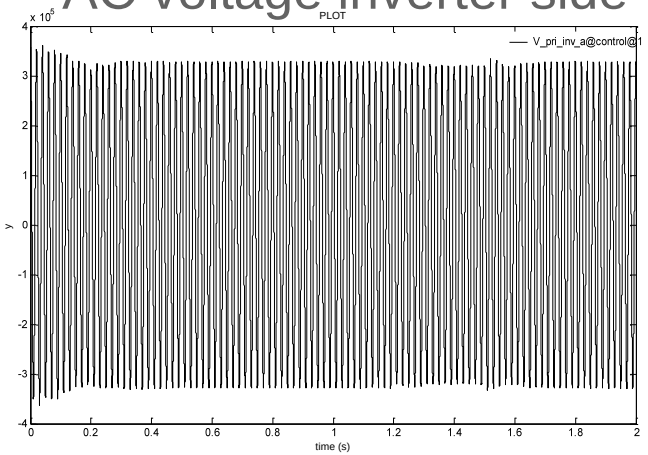
Detailed HVDC model

Voltage sag

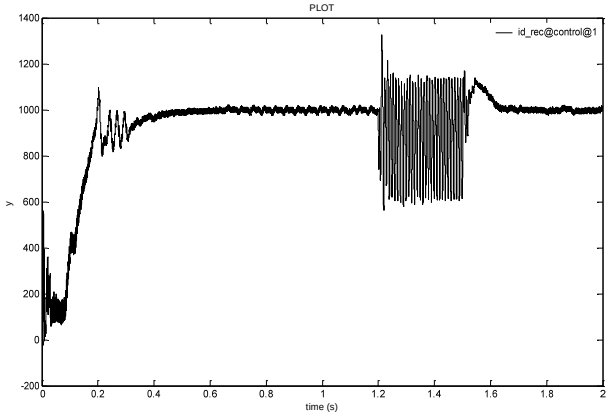
AC voltage rectifier side



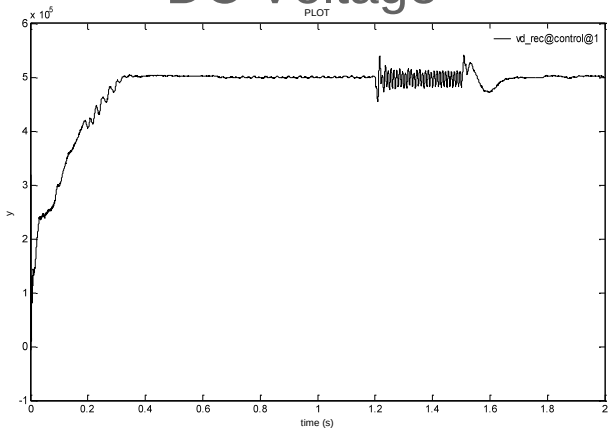
AC voltage inverter side



DC Current



DC Voltage



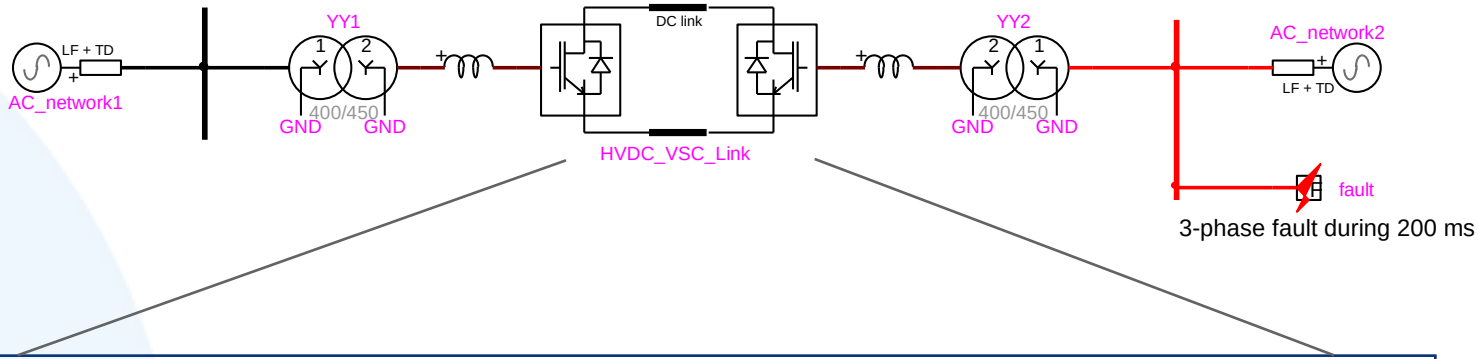
Detailed HVDC model, next developments

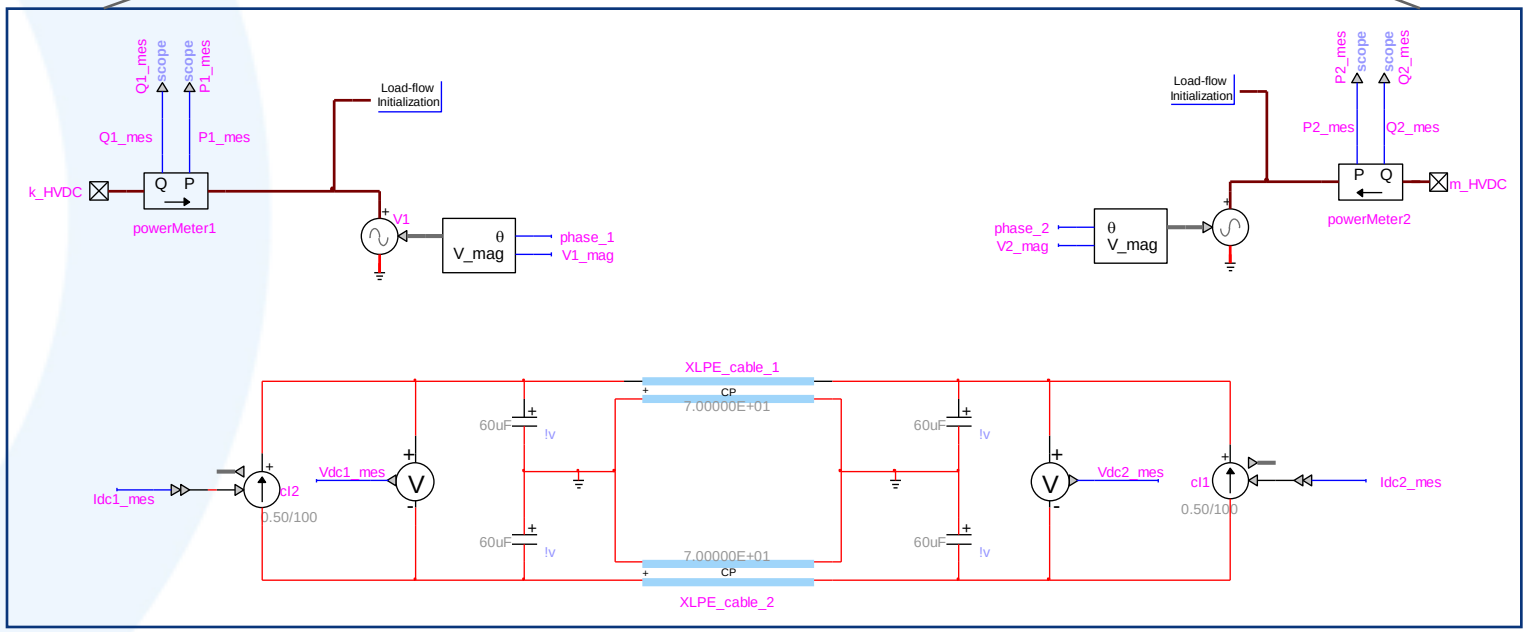
- Available on demand
- Implementation of the Voltage Dependent Current Limit Unit :
  - Static characteristic adapts I_{ref} as a function of DC voltage
  - Dynamic characteristic adapts I_{ref} as a function of DC voltage according to the fast down time and slow up time
- Modeling of protection systems (overvoltage, overcurrent, commutation failures)
- Implementation of start up algorithm
- Integration of control systems designed by manufacturers (DLL connection) to obtain specific HVDC models

Average HVDC VSC model

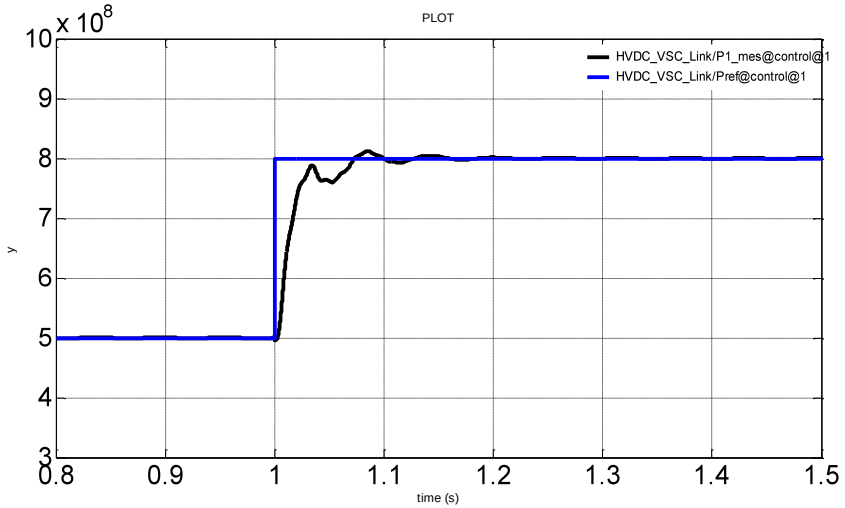
- Main Characteristics :
  - Rated power : 1200 MVA
  - DC voltage : +/- 320 kV
  - DC cable 2500 mm² XLPE insulation, 70 km
  - Converters transformers
  - AC & DC filters
  - Capacitor bank : 20 µF
  - AC short circuit power : 6000 MVA
  - Control system :
    - Active power regulation
    - DC voltage regulation
    - Reactive power regulation
- Developed by EDF R&D

Average HVDC VSC model

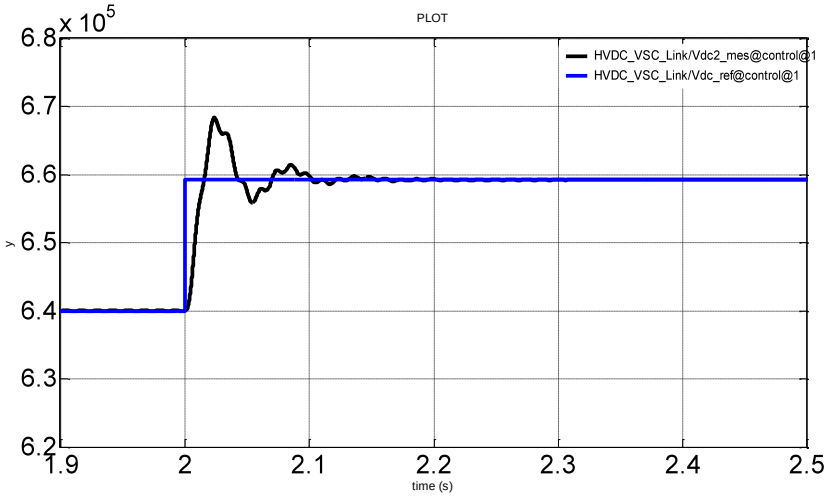




Average HVDC VSC model



Active power step change



DC voltage step change

Simulation options : $\Delta t = 50\mu s$, $t_{max} = 3s$, CPU time = 4.2s

HVDC VSC model – Next developments

- Reactive power controller has to be improved
- Contribution to CIGRE WG B4.38 (Simulation of HVDC and FACTS)
- Implementation of manufacturer controllers models using DLL connection to obtain specific HVDC models
- Available on demand