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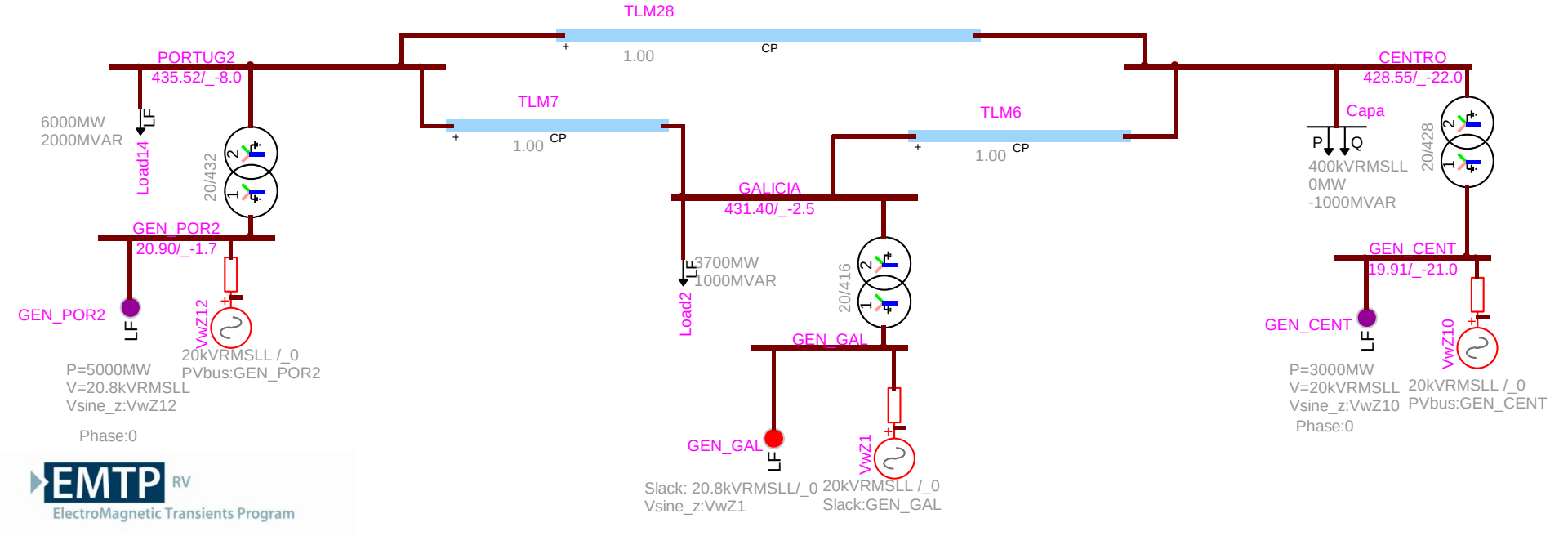
ÉCOLE POLYTECHNIQUE MONTRÉAL




# The France-Spain HVDC link

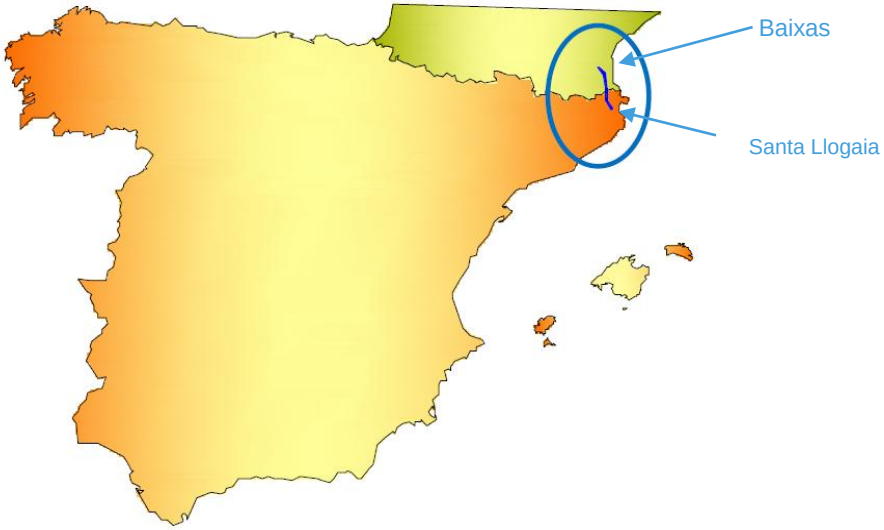
## HVDC VSC MMC modeling challenges, Monday June 20, 2011

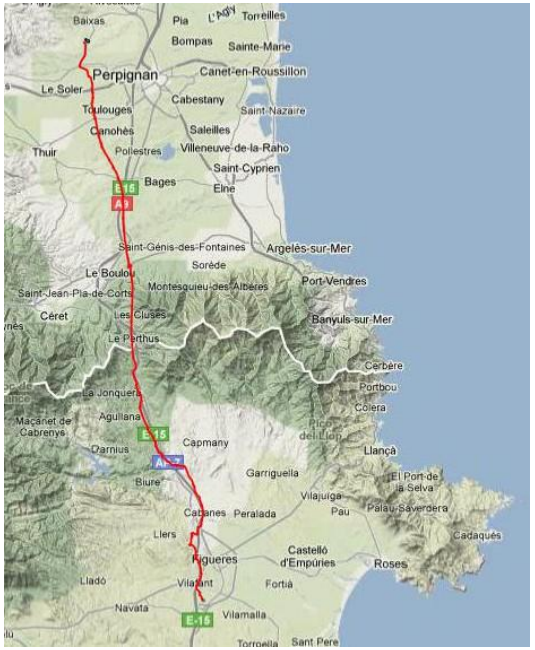
EMTP User Group Meeting, Clamart, France

Sébastien Dennetière (RTE), Hani Saad (Ecole Polytechnique de Montréal)

# Project Presentation

A 2000 MW - 65 km underground cable – DC link connecting Baixas (near Perpignan, France) and Santa Llogaia (near Figueras, Spain)



# Key Features
# France Spain HVDC Link

**Rated power**: 2*1000 MW

**DC voltage**: ±320 kV for each 1000MW link

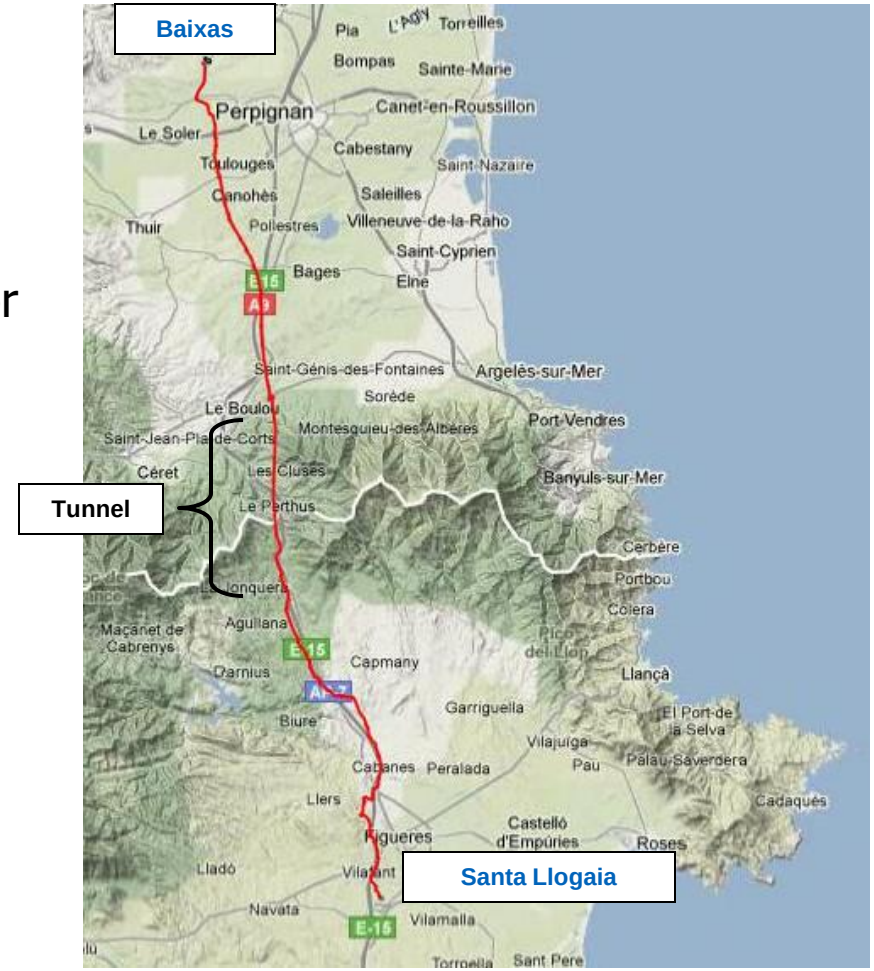
**Reactive Power Control**: +/- 300 MVAR for each 1000MW Converter Stations

**Converter Contractor** : Siemens
Connected in a meshed AC network

**DC cable length**: 64 km

**Cable Contractor**: Prysmian
8 km dedicated Tunnel

**Commisioning date**: 1st half 2014



Thesis:
Modelling and Real Time Simulation of the MMC-based HVDC link

Hani SAAD

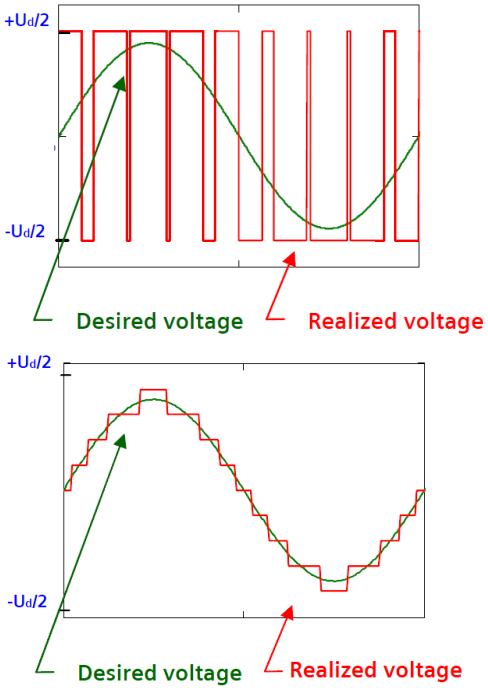
Universities:
Director: Jean Mahseredjian, École Polytechnique de Montréal
Co-director: Xavier Guillaud, École Centrale de Lille

Industrial partner: RTE
Project co-directors: Sébastien DENNETIERE and Samuel NGUEFEU

Modular Multilevel Converter (MMC) has become a highly attractive topology for medium and high voltage applications. It is a new type of multilevel voltage source converter (VSC).

Advantages of the MMC over the classical VSC types : NPC, multilevel FC etc.

- Low frequency modulation
- Lower transient peak voltages on IGBT -> Less losses
- Very low THD -> no need for High-pass Filters



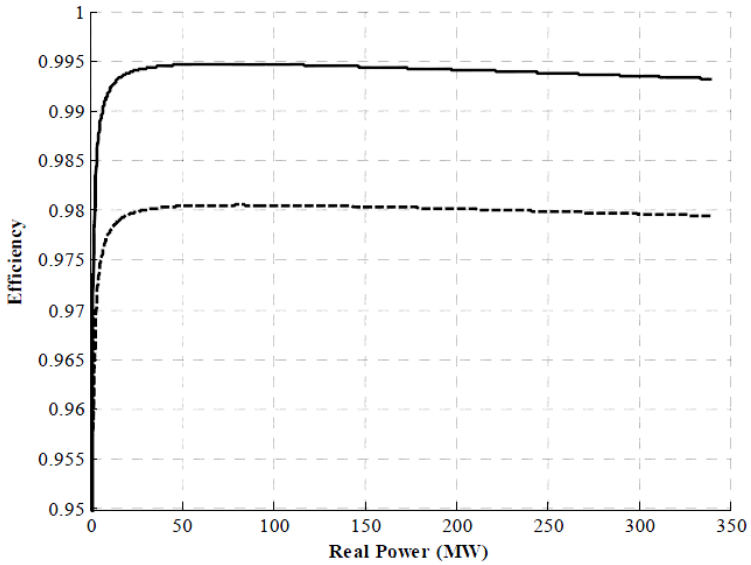
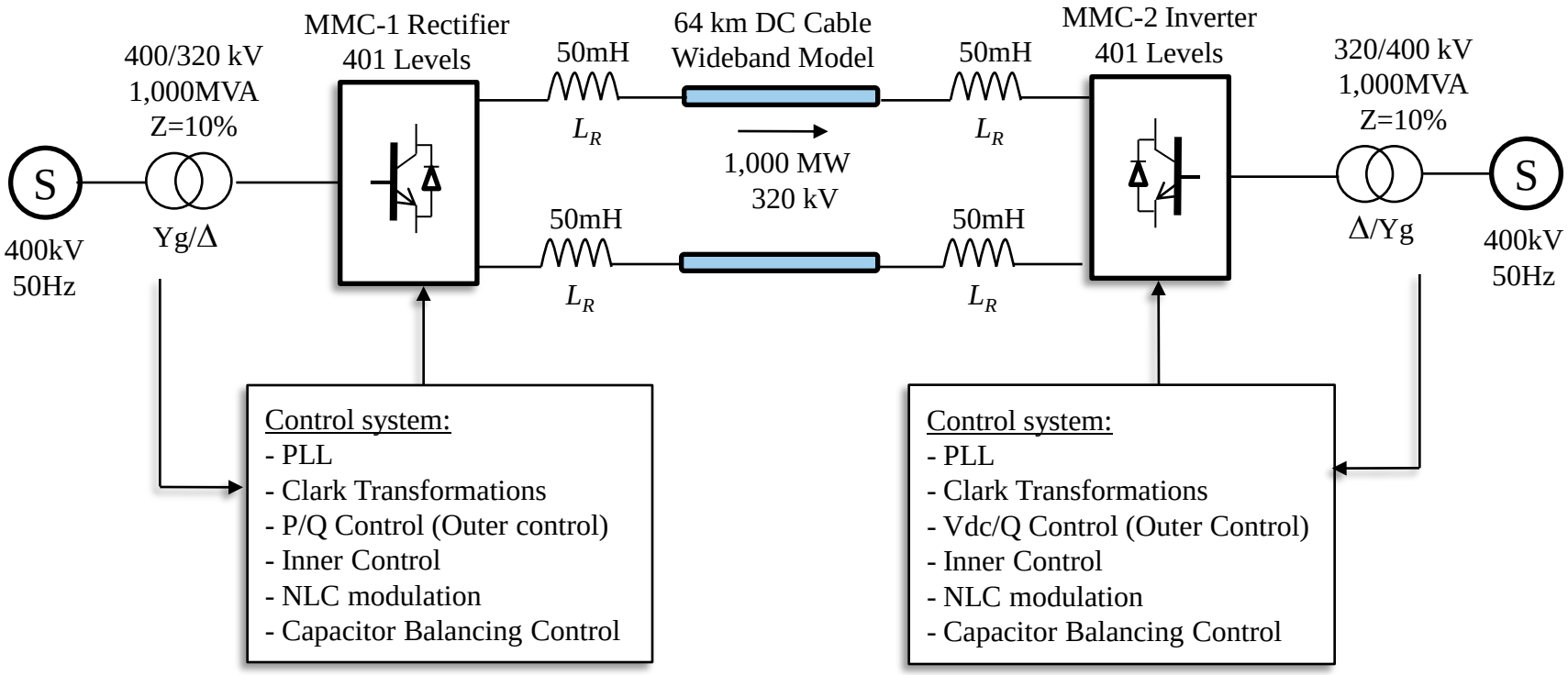



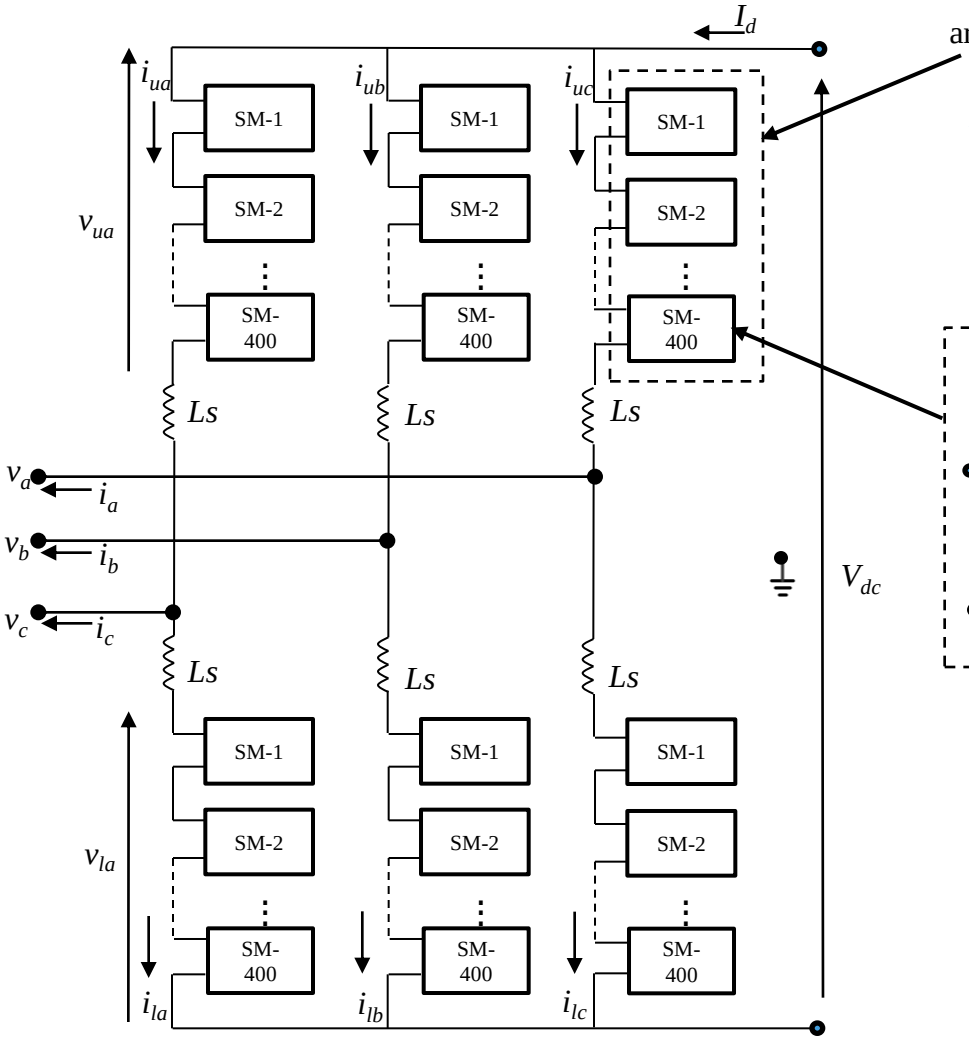

Fig. 10: Efficiency of the 2level and M2C (cos φ = 0.88)

- Solid line: M2C
- Dashed line: 2level

# Overview of the HVDC VSC-MMC system

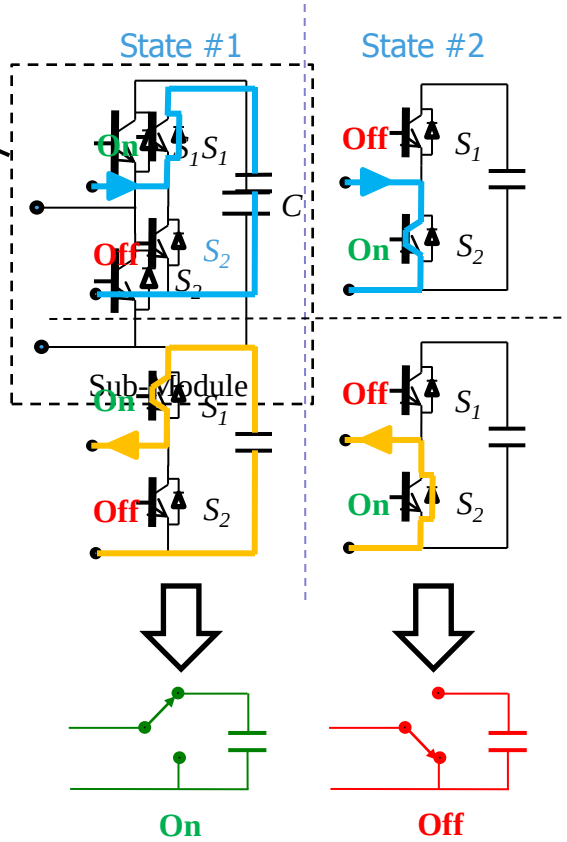


# Overview of the MMC topology

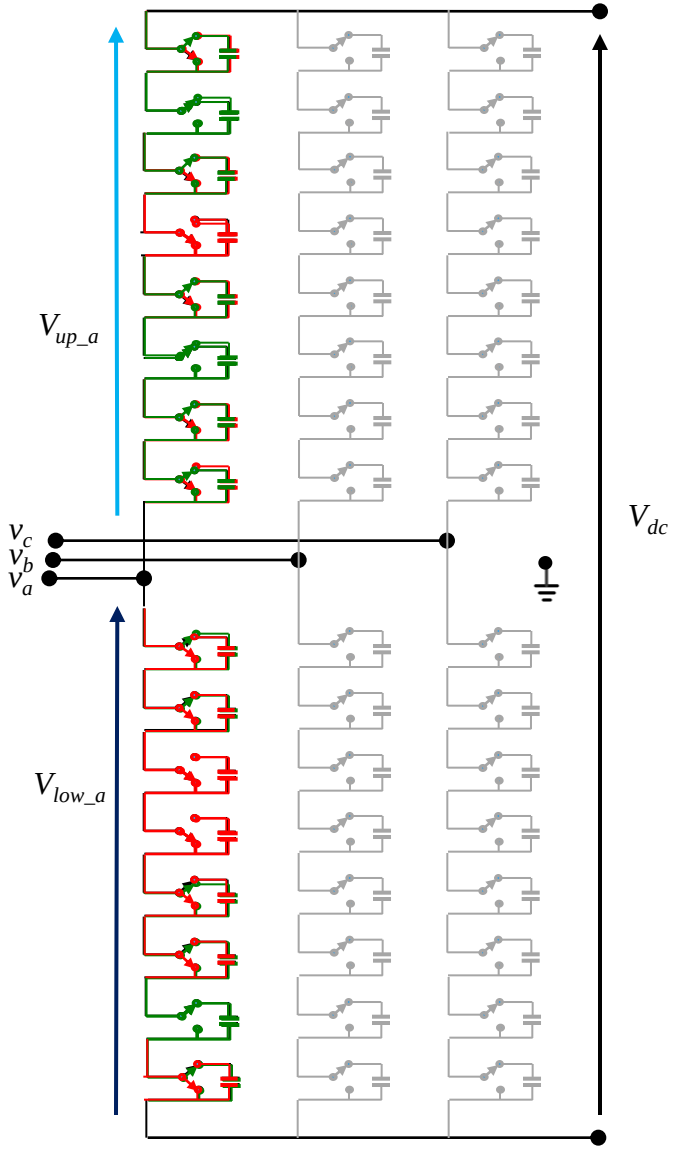



At normal operation, S1 and S2 are complementary

- The sub-module consist of two states:
  - S1->on and S2->off
  - S1->off and S2->on

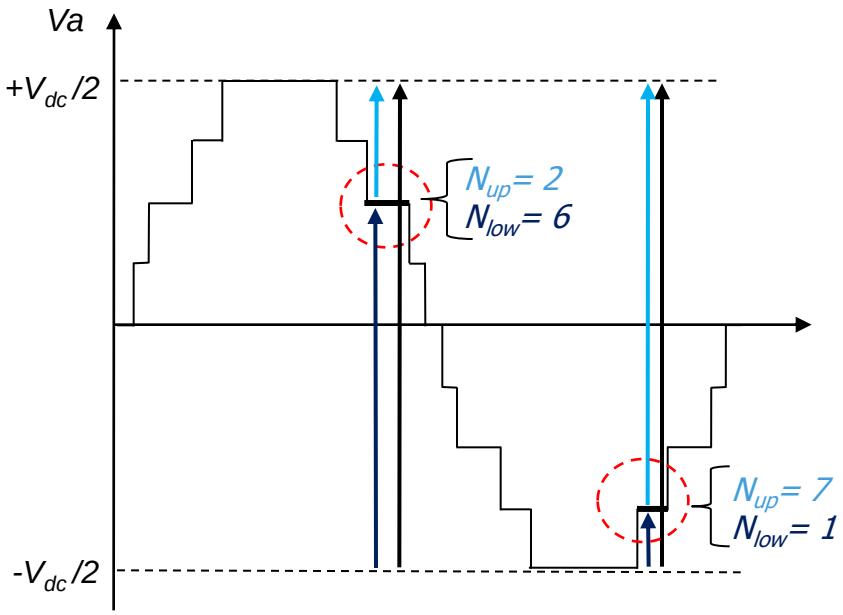


# Example: Suppose we have a MMC-9levels




$$v_{up\_a} = \sum_{i=1}^{N_{up}} (S_{up\_ai} \cdot vc_{up\_ai})$$

$$v_a = -v_{up\_a} + \frac{V_{dc}}{2} = v_{low\_a} + \frac{V_{dc}}{2}$$

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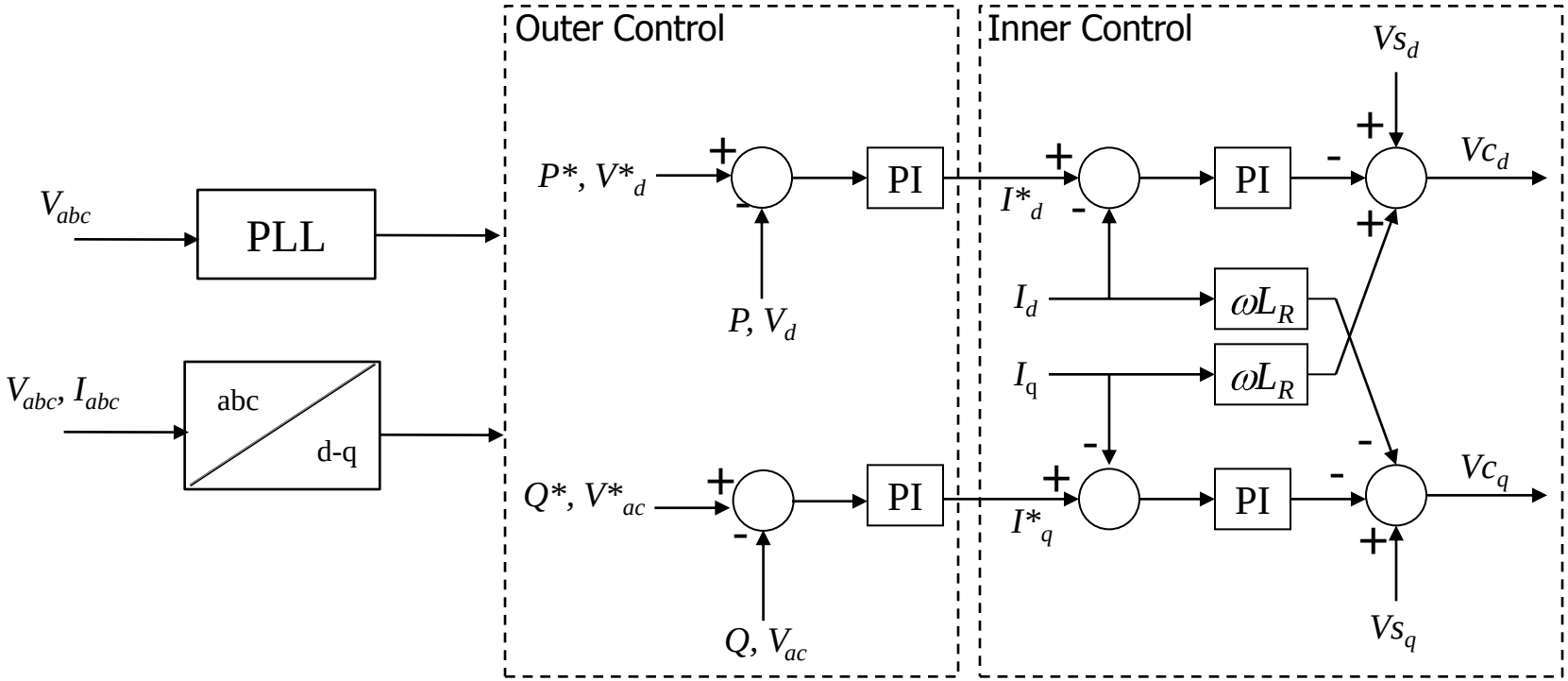
# The Outer/Inner controls are similar to the standard VSC-HVDC systems

## Outer control:

- Active and Reactive power are controlled at the rectifier side
- DC voltage and Reactive Power are controlled at the inverter side



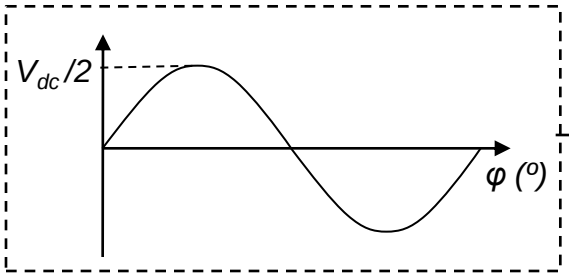
Different modulation techniques exists: .
For MMC with very high levels, the NLC modulation is very appropriate, keeping a low switching frequency and very accurate waveform

## NLC modulation (Nearest Level Control):

Pre-calculation of angles :

$$\theta_{(k,k+1)} = \arcsin\left(\frac{k}{M}\right)$$

$$\left(M = \frac{N-1}{2}, k = 1,2,\ldots, M\right)$$



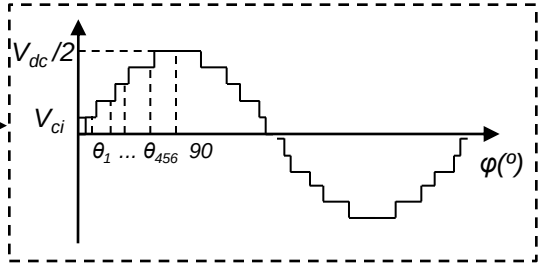

Reference voltage

Voltage transformation of the voltage waveform in degree

$\theta = \arcsin(Vac)$

Pour : $\theta_{(k-1),k} < \varphi_k \leq \theta_{k,(k+1)}$

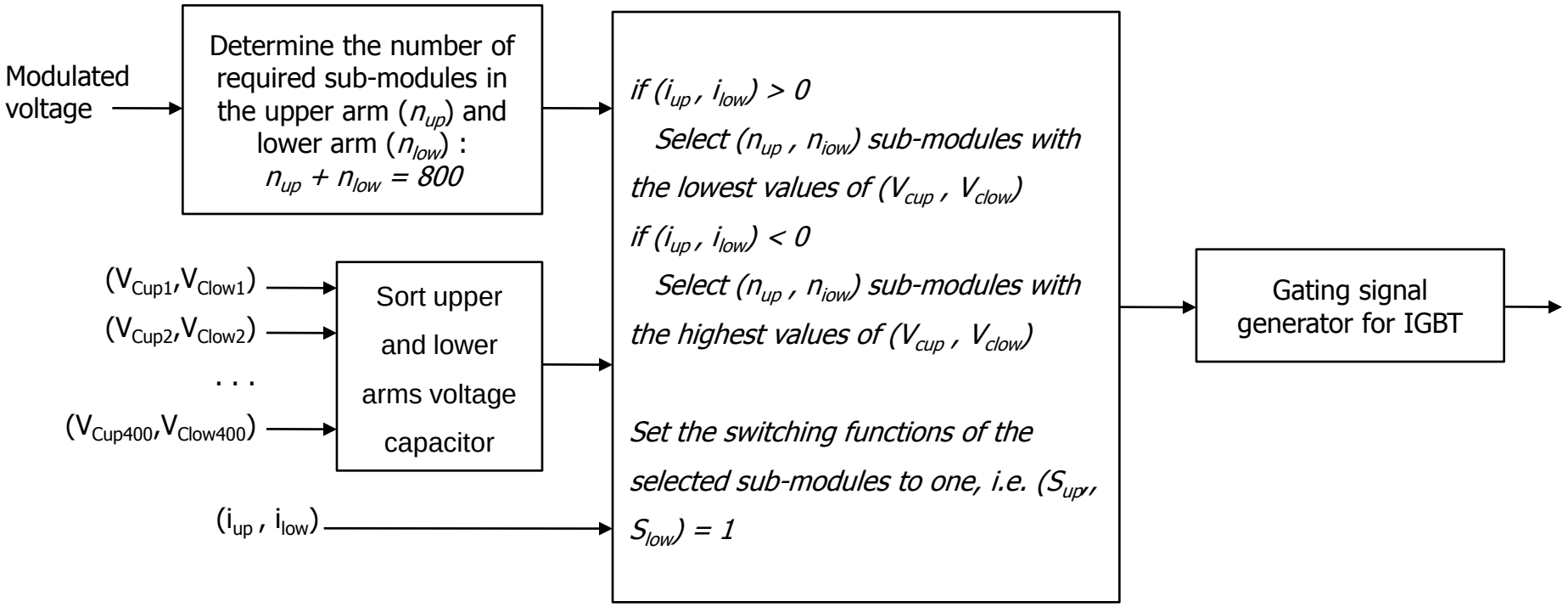
➢Select number of level



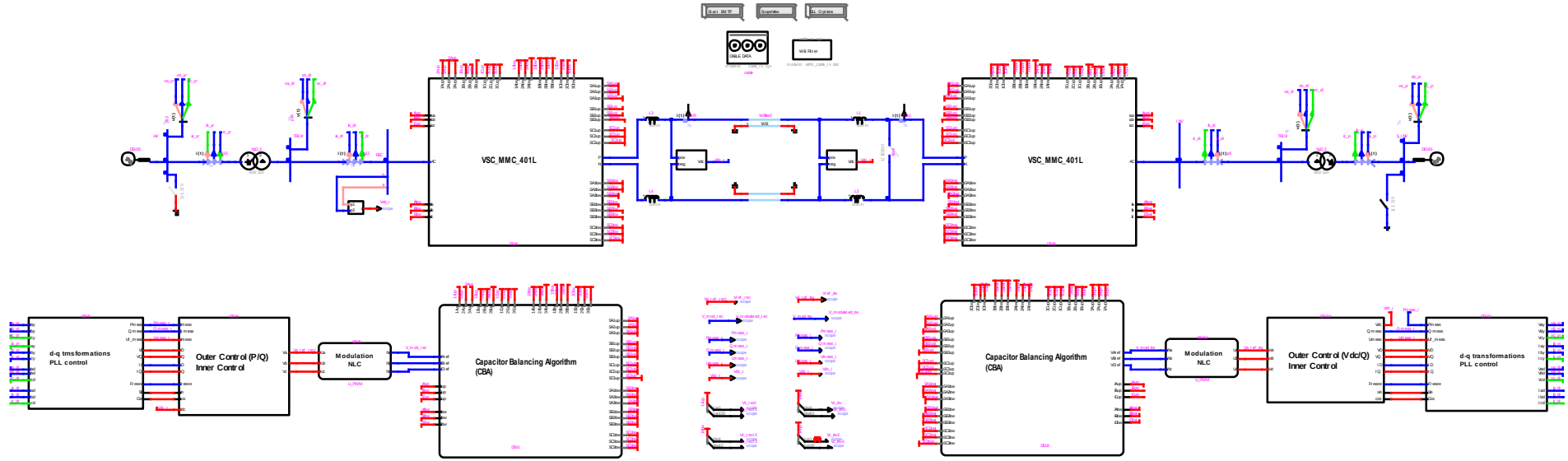

Modulated voltage

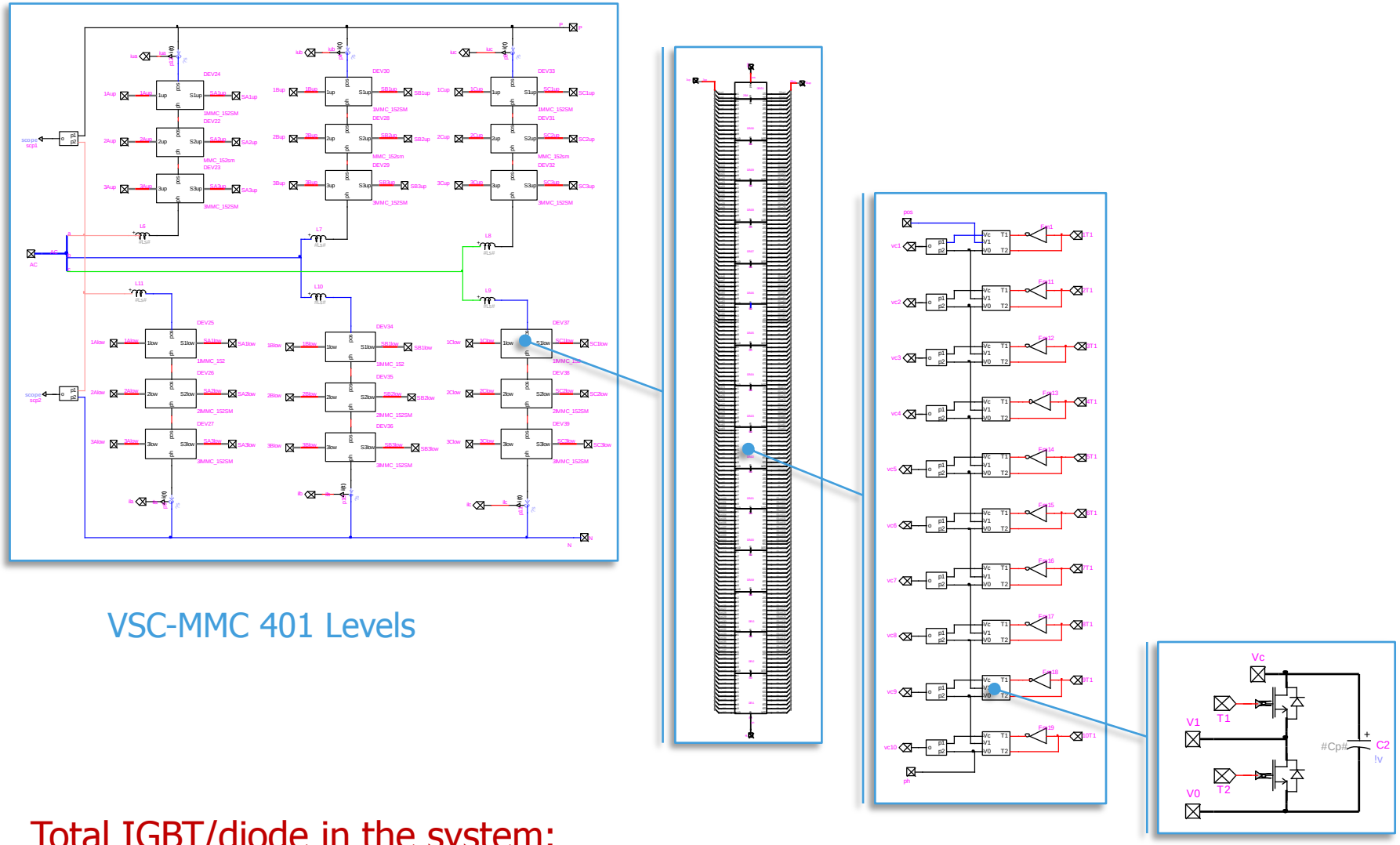
# Balancing Control Algorithm (BCA)

## Objective: keep the different capacitor voltages of each SM near the average nominal value



# MMC-based HVDC 401 levels system in EMTP-RV


VSC_MMC_401L
VSC_MMC_401L
d-q tmsformations
PLL control
Outer Control (P/Q)
Inner Control
Modulation
NLC
Capacitor Balancing Algorithm
(CBA)
Capacitor Balancing Algorithm
(CBA)
Modulation
NLC
Outer Control (Vdc/Q)
Inner Control
d-q transformations
PLL control




VSC-MMC 401 Levels

Total IGBT/diode in the system:
2(IGBT/SM)*400(SM/arms)*2(arms/phase)*3(phases)*(converters)
= 9 500 IGBTs with antiparallel diodes

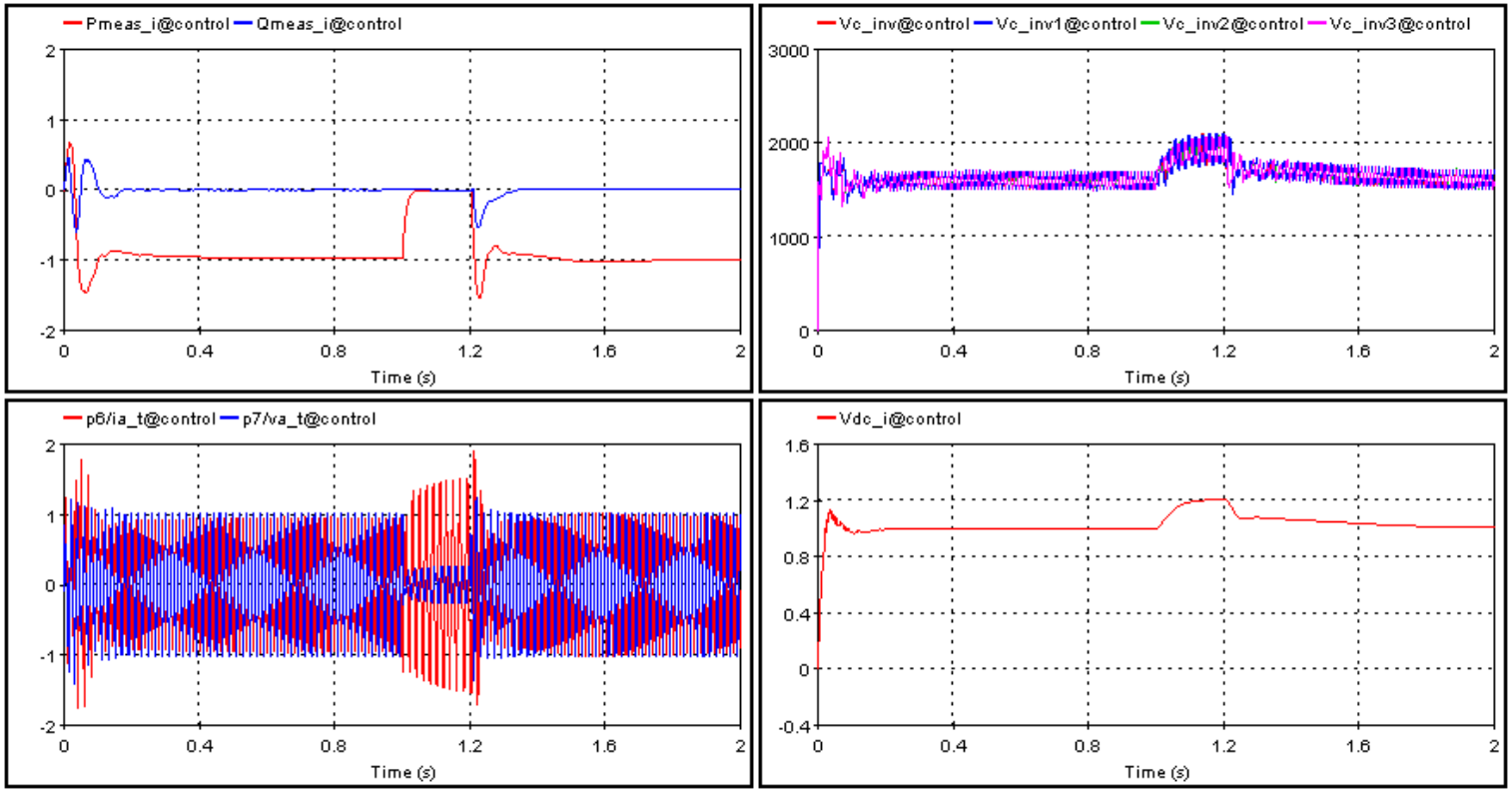
## Simulation results :

For t=2 s:

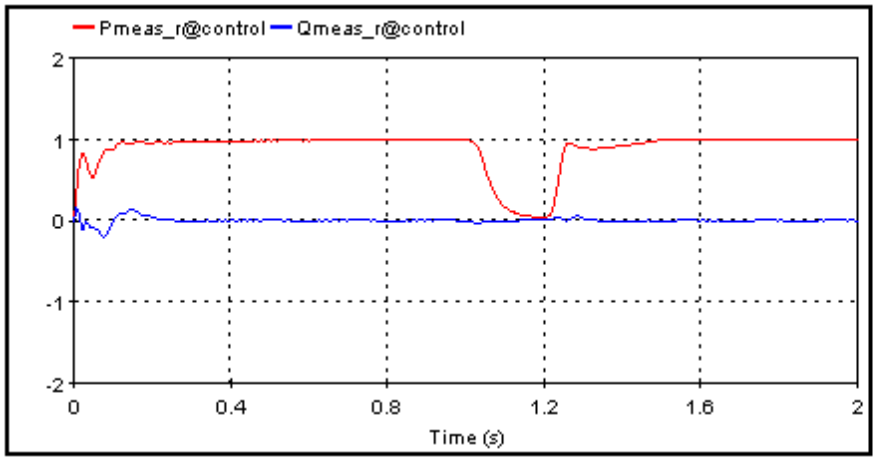
-> Run time for simplified model= 30min 10s

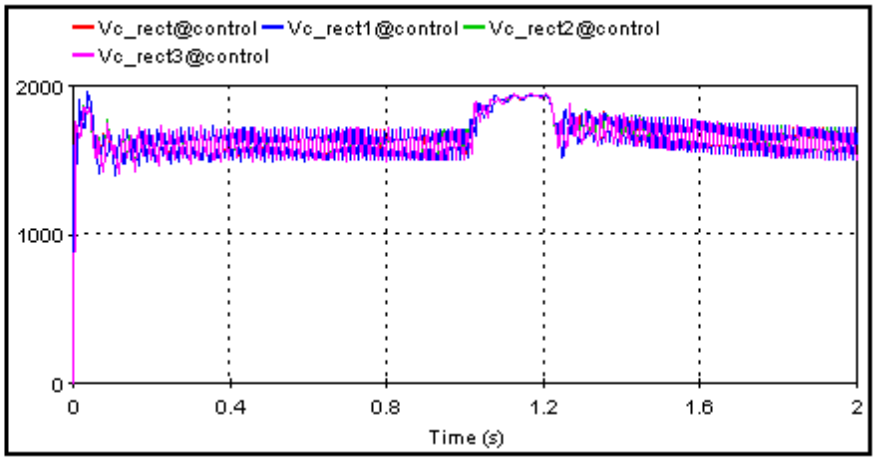
-> Run time for detailed model= 3h 20min

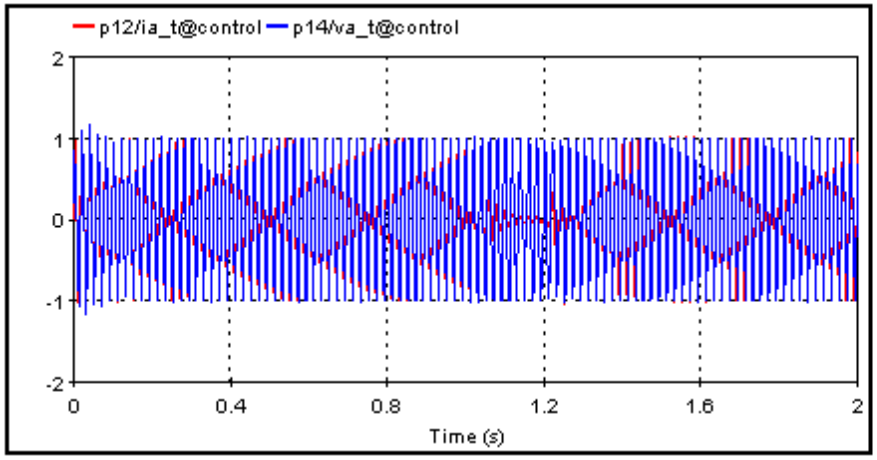
## Inverter Side

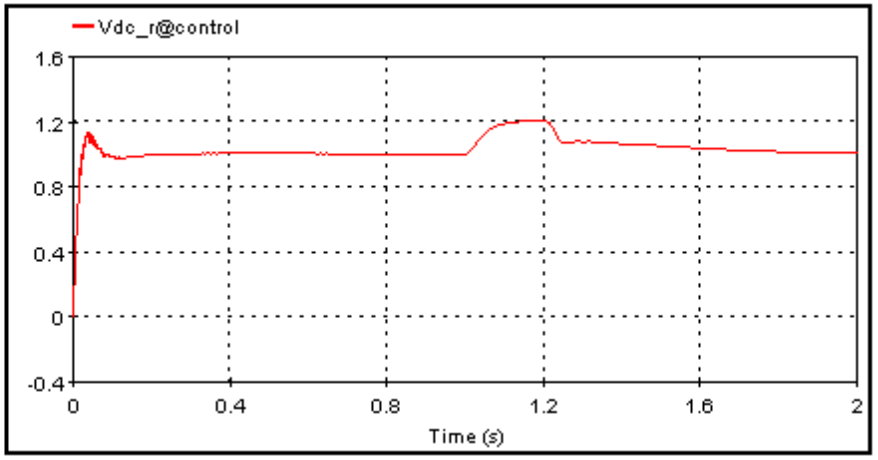


# Rectifier Side

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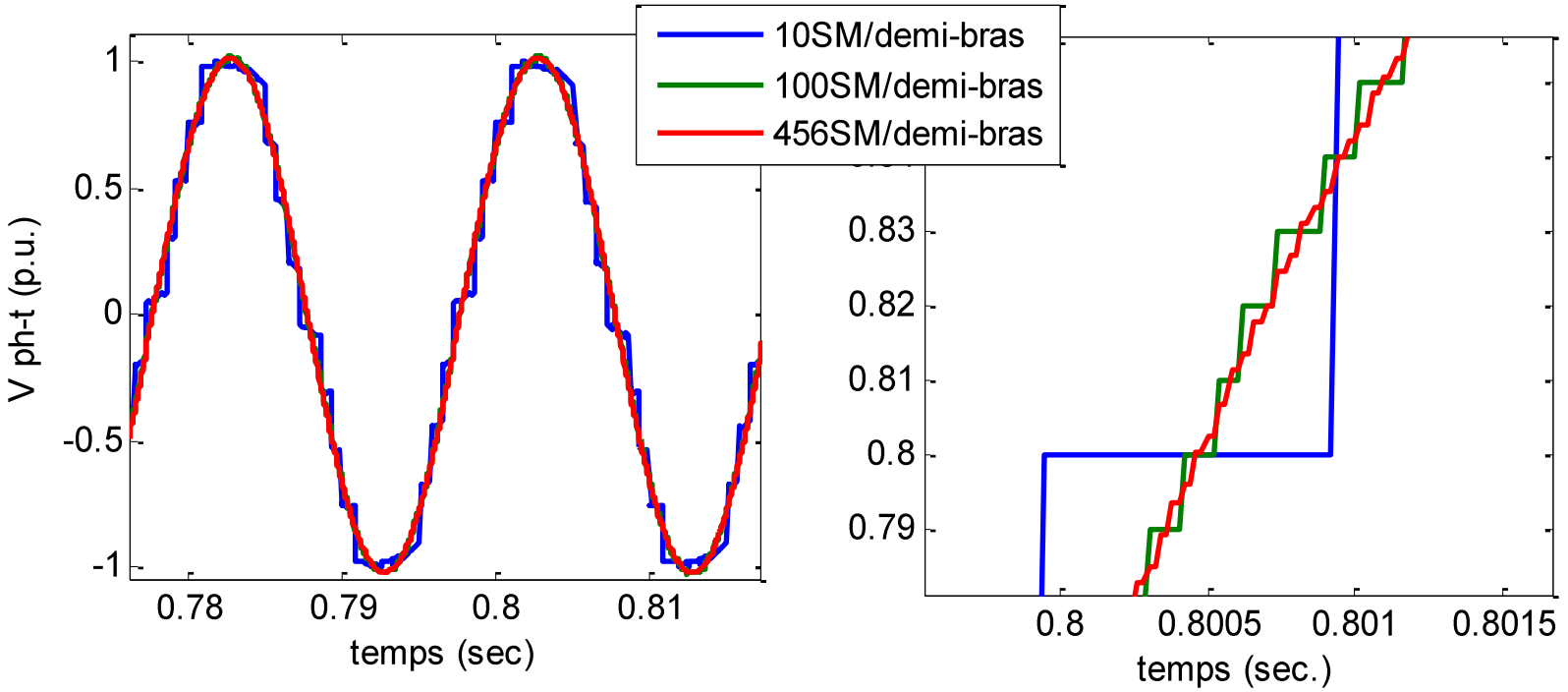
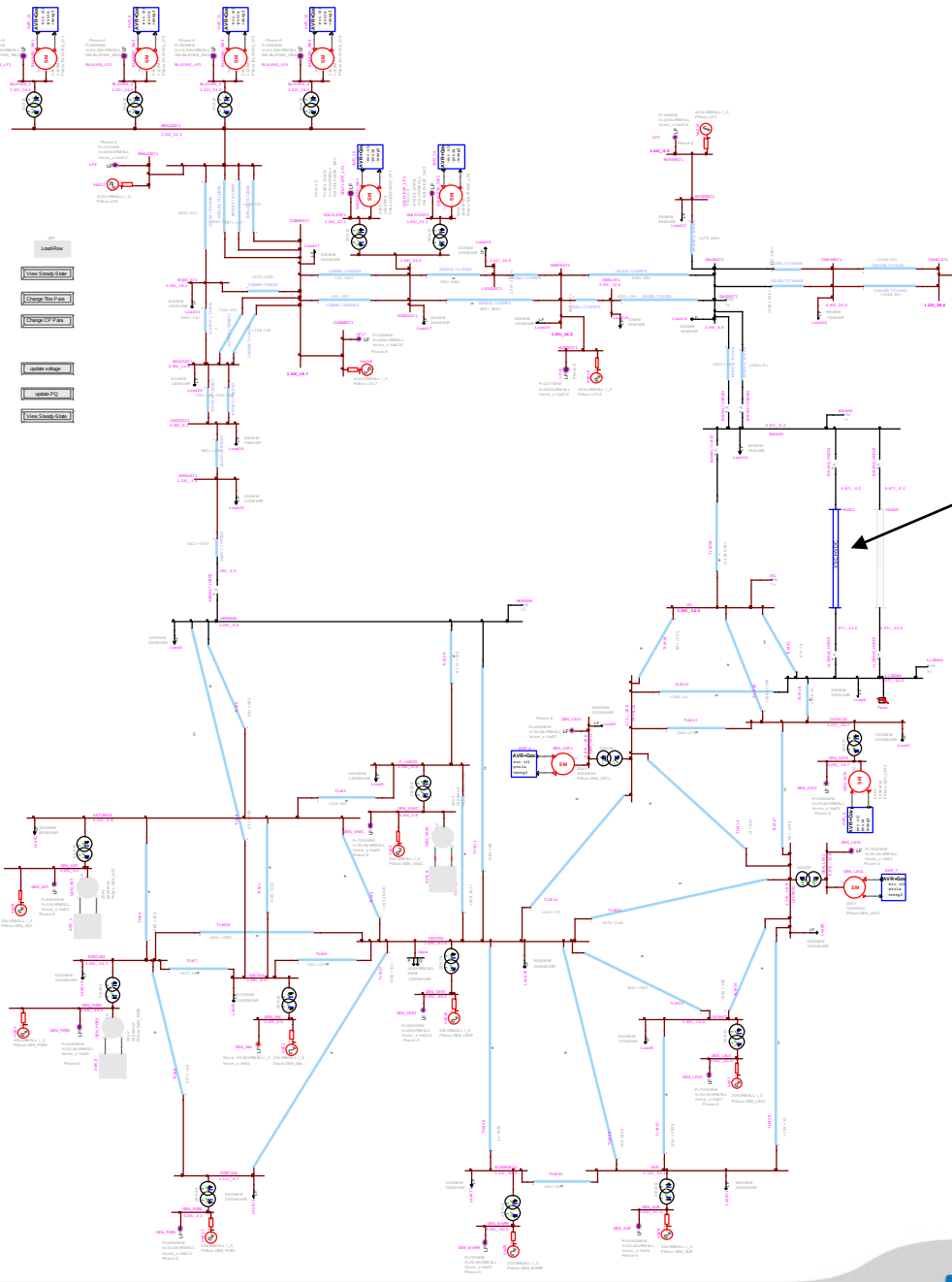
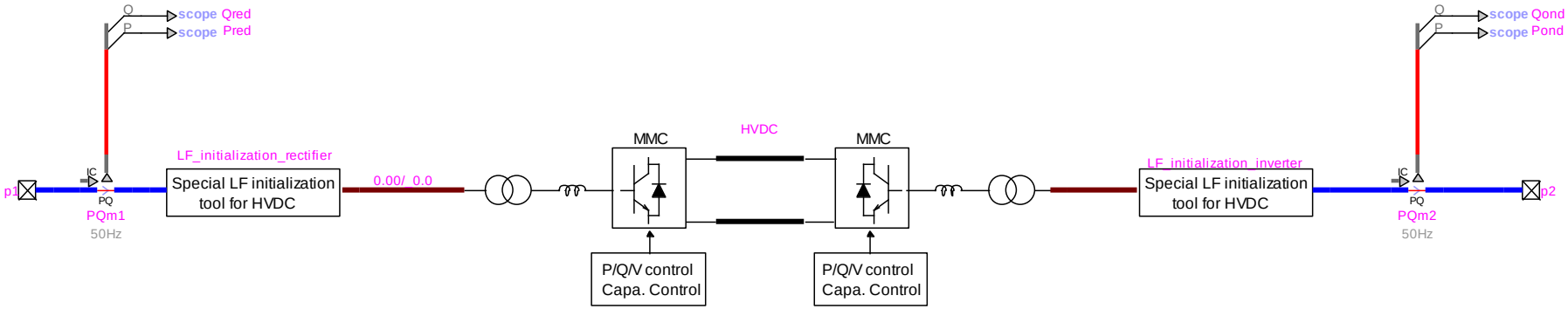

10SM/demi-bras
100SM/demi-bras
456SM/demi-bras
V ph-t (p.u.)
1
0.5
0
-0.5
-1
0.78
0.79
0.8
0.81
temps (sec)
0.83
0.82
0.81
0.8
0.79
0.8
0.8005
0.801
0.8015
temps (sec.)

# 22 synchronous machine




Q
P
scope Qred
scope Pred
IC
PQ
PQm1
50Hz
p1
LF_initialization_rectifier
Special LF initialization tool for HVDC
0.00/ 0.0
MMC
HVDC
MMC
P/Q/V control
Capa. Control
P/Q/V control
Capa. Control
LF_initialization_inverter
Special LF initialization tool for HVDC
Q
P
scope Qond
scope Pond
IC
PQ
PQm2
50Hz
p2