Réseau de transport d'électricité

LILLE

Modelling and analysis of Multi-terminal HVDC grid

Ph.D. with RTE / Ecole Centrale de Lille

(2011-2013)

CNER / Département Postes

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April 3rd 2012

Outline

1) Context
   1) TWENTIES project
   2) Thesis objectives
2) VSC modelling
3) AC/DC Initialization
4) Conclusion

The TWENTIES wind energy project

Secure large-scale integration of wind power into the European electricity grid

- Demonstration project
- Lunched by EU
- 62 M€ (32M€ Directly provided by EU)
- 26 Electrical companies & Research institutions
- 10 Member states are represented
- Coordinated by Red Eléctrica de España

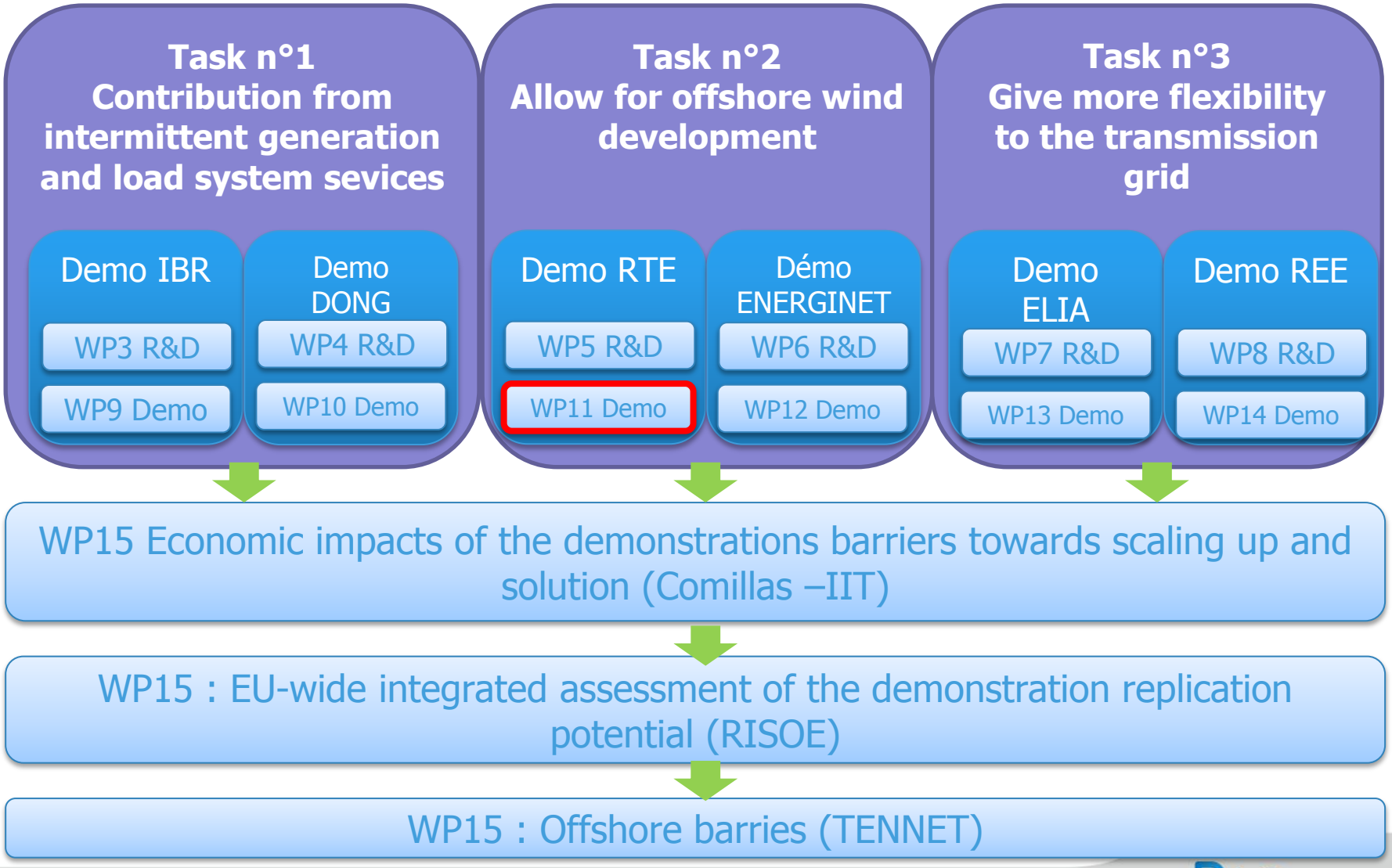
➢ RTE task: Improving safety and security for offshore wind generation

- Control & protection to roll out HVDC grid

➢ Further information

- http://www.twenties-project.eu

Twenties : Work-Package content



Demo 3

1) Main objective

1) Assess main drivers for the development of offshore HVDC networks

2) Approach

1) Optimal planning and operation of AC/DC interconnected power systems
2) Local control of HVDC networks
3) Design and quantify experimental DC networks (N-1, faults)
4) Design and test control functions, protection systems …
5) Benchmark several network topologies

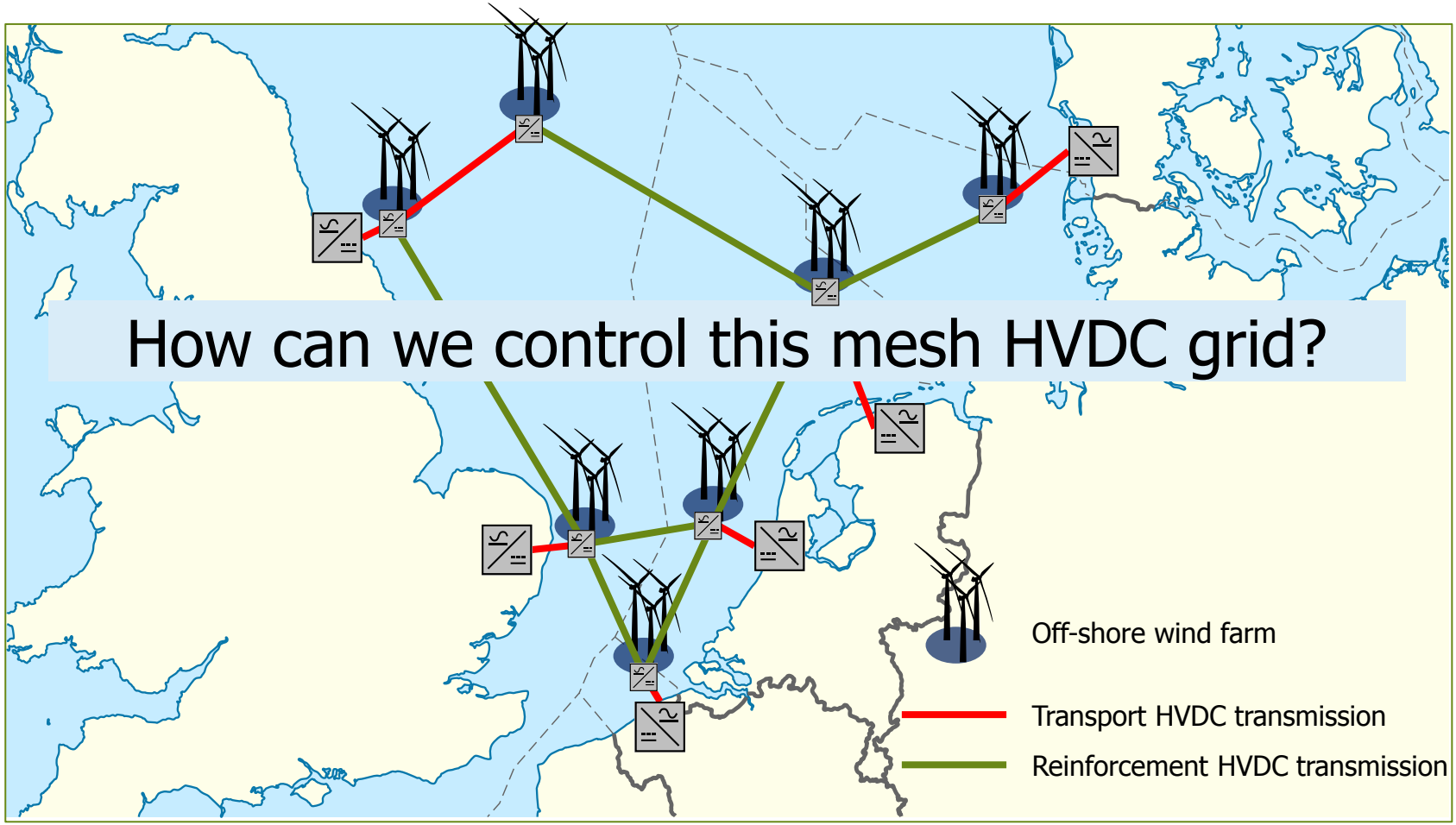
Protection and fault recovery in MTDC Grid
J. Descloux

2 PhD

Control of MTDC Grid
P. Rault

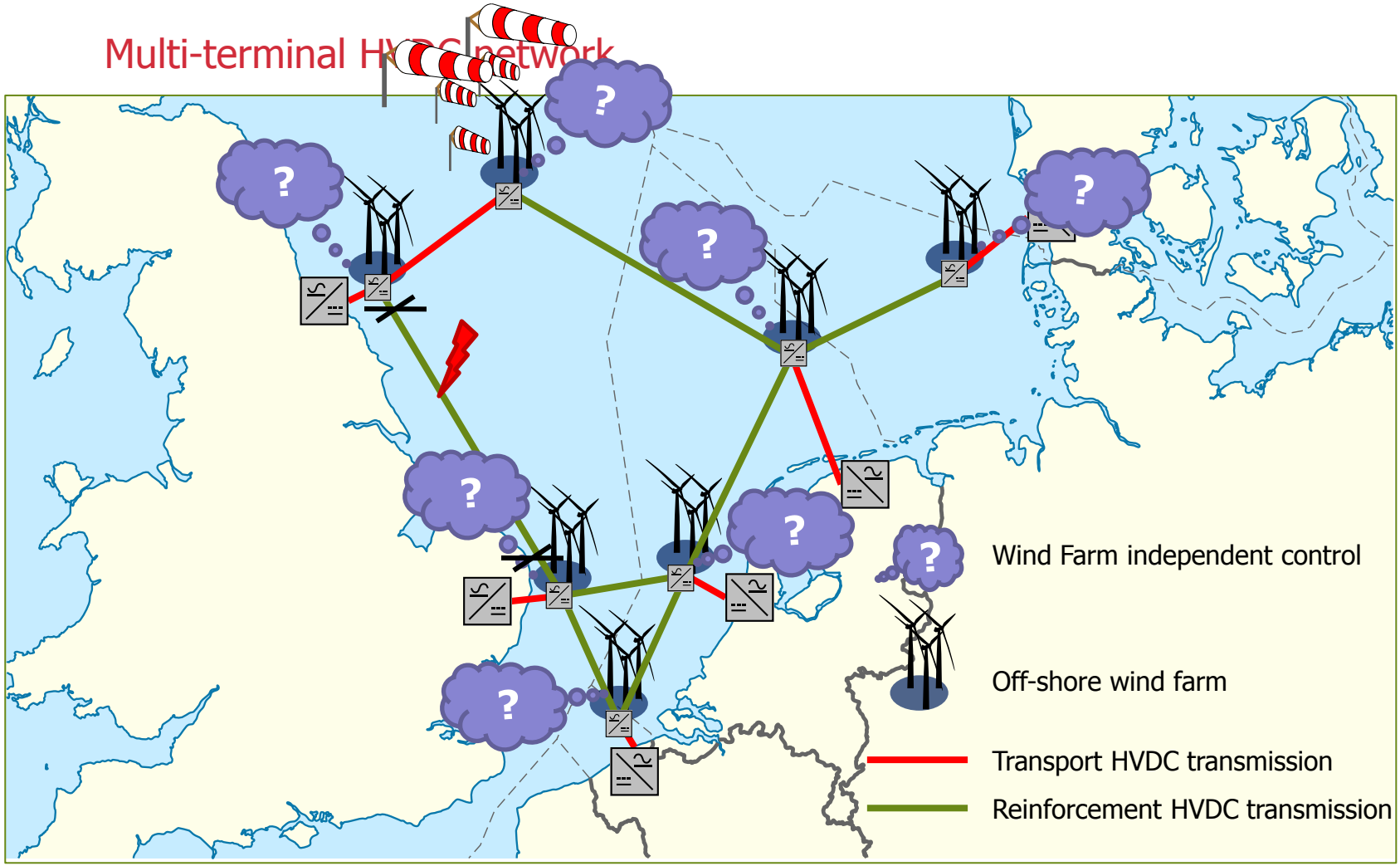
PhD thesis objective

Multi-terminal HVDC network



PhD thesis objective

Multi-terminal HVDC network



Outline

1) Context

2) VSC modelling

   1) Power part

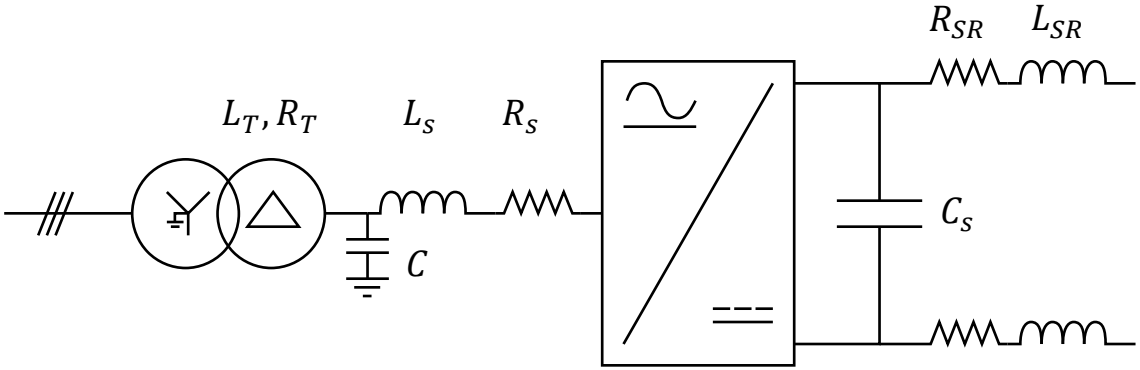
   2) Converter

   3) Control part

3) AC/DC Initialization

4) Conclusion

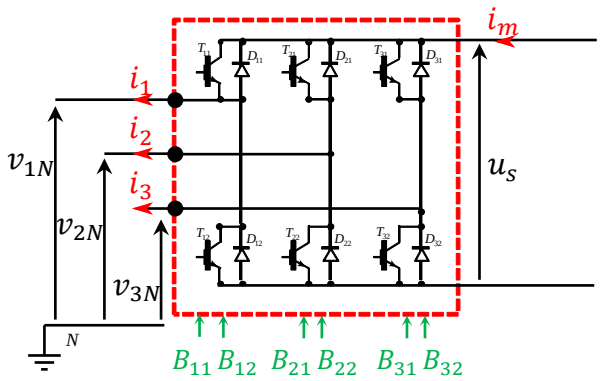
Substation model : power part



Device	Characteristics	Values (mks)	Values (pu)
Transformer Yd	U1 (primary)	400kV	1pu
	U2 (secondary)	320kV	1pu
	Apparent power	1500MVA	1pu
	Lcc (secondary)	32.6mH	0.15pu
	Rcc (secondary)	0.34Ω	0.005 pu
LC Filter	C	6.2µF	7.5pu
	L_s	32.6mH	0.15 pu
Capacitor	C_s	50 µF	5.6 ms
Smoothing reactor	R_{SR}	0,01Ω	
	L_{SR}	10mH	

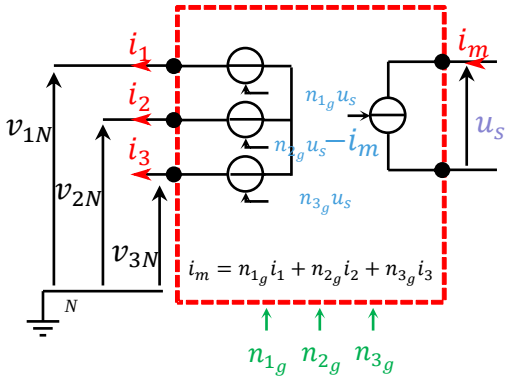
Converter modeling

Instantaneous model



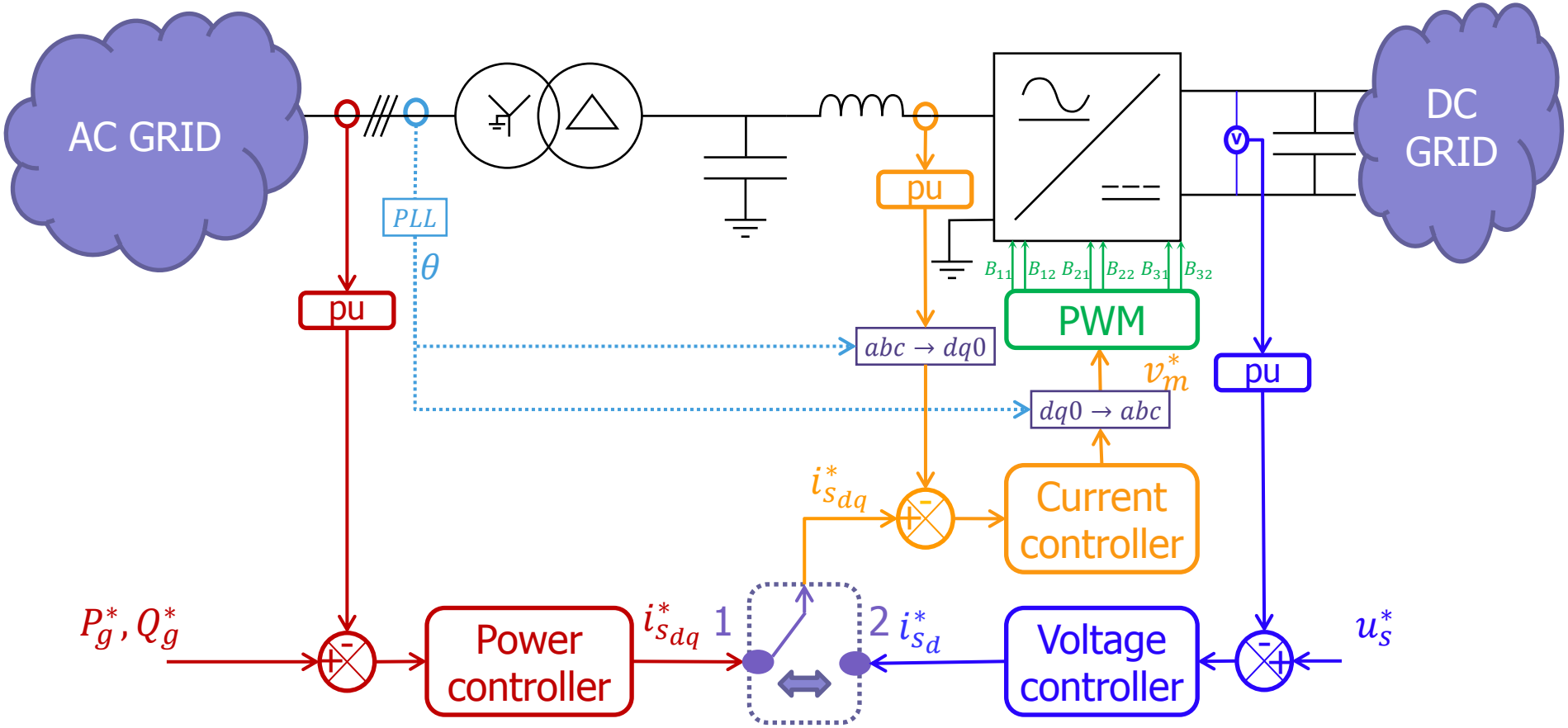
- → Continuous mode
- → Discontinuous mode
- → B_{ij} : IGBT control signal

Mean-time model



- → Continuous mode
- → Mean values
- → n_{i_g} : Mean Conversion function
- → $n_{i_g} = \frac{1}{T_e}\int_{kT_e}^{(k+1)T_e} n_i dt$
- → $v_{iN} = n_{i_g} u_s$
- → $i_m = \sum n_{i_g} i_i$

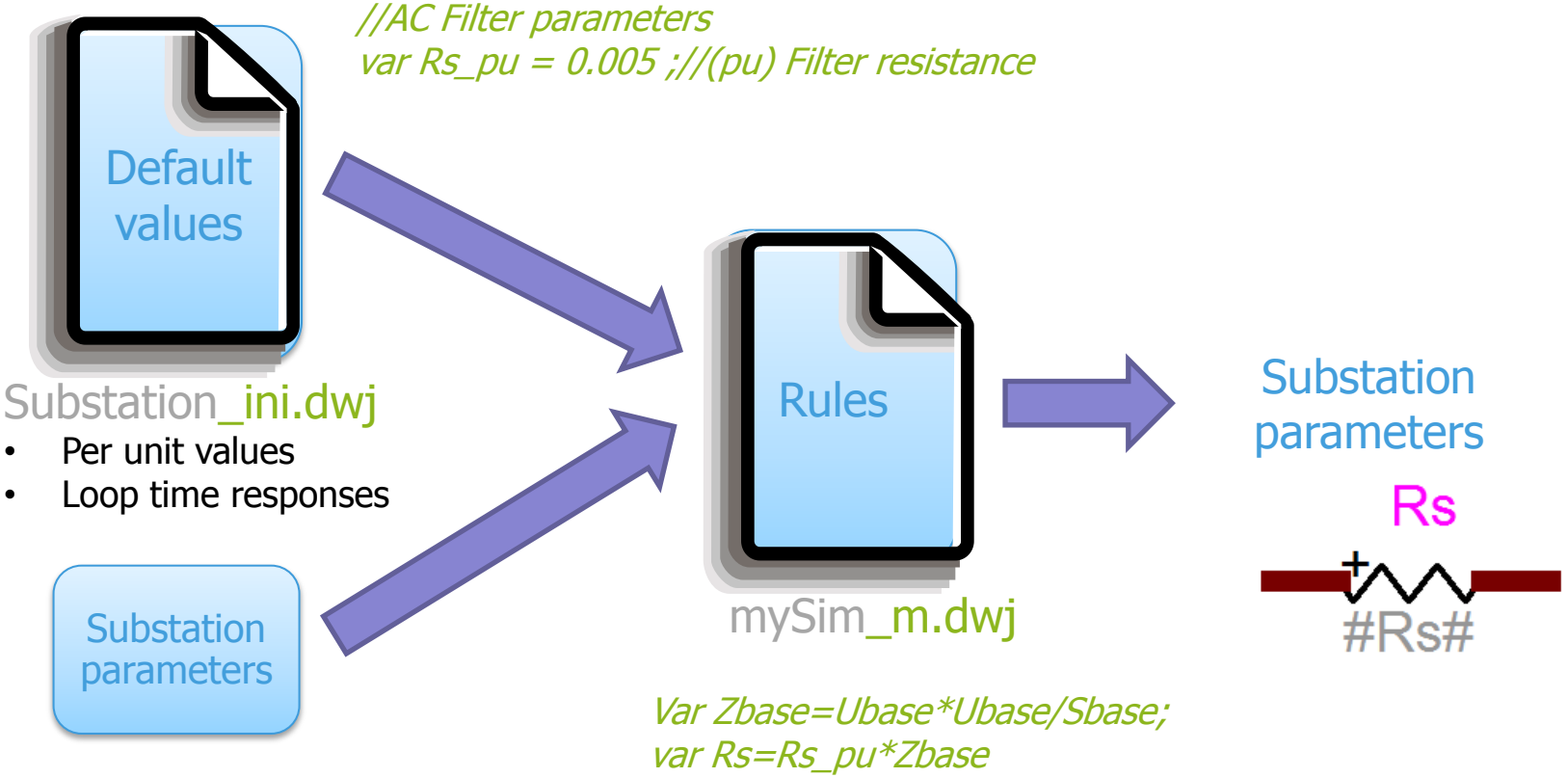
VSC: control


AC GRID
DC GRID
PLL
θ
pu
pu
pu
B_{11} B_{12} B_{21} B_{22} B_{31} B_{32}
PWM
$abc \rightarrow dq0$
$dq0 \rightarrow abc$
v_m^*
$i_{s_{dq}}^*$
Current controller
P_g^*, Q_g^*
Power controller
$i_{s_{dq}}^*$
1
2
$i_{s_d}^*$
Voltage controller
u_s^*

Outline

1) Context
2) VSC modelling
3) AC/DC Initialization
    1) Substation parameters
    2) DC part initialization
    3) AC part initialisation
    4) Control part initialization
    5) Start AC/DC simulation from steady state
4) Conclusion

Substation parameters



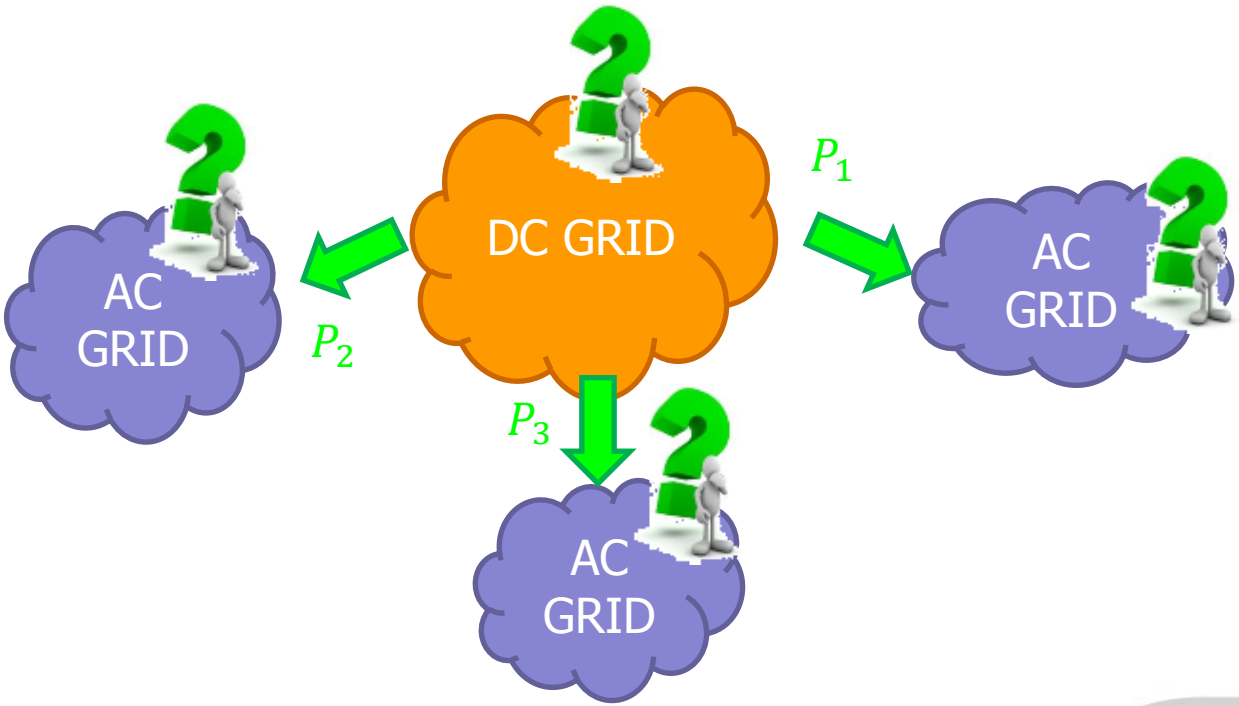
Specific initial values

- Nominal power
- Power reference

Ubase=640e3;//(V)
Sbase=1000e6; //(VA)
PM0 = -500e6; //(W)

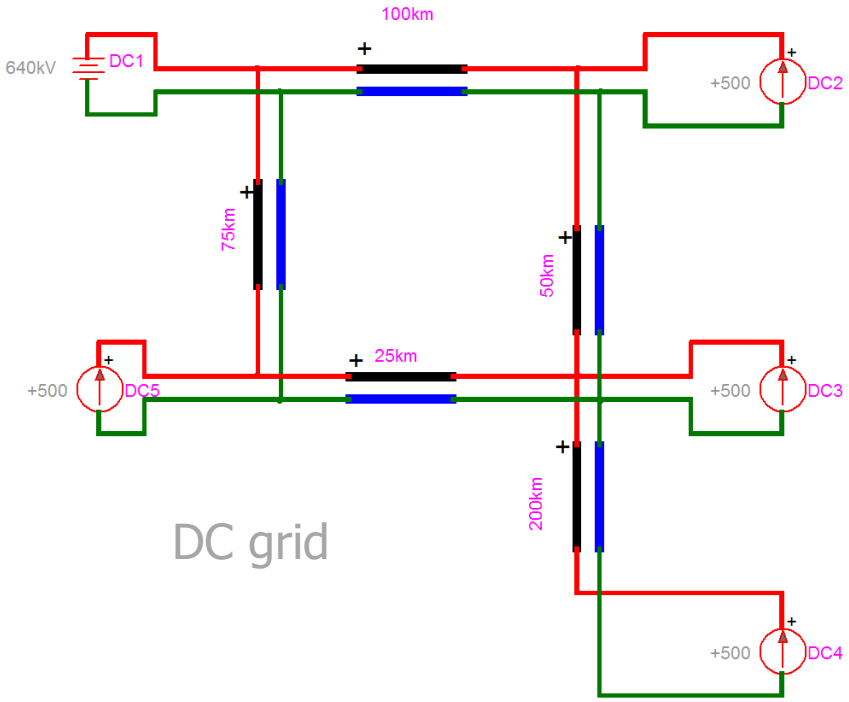
Objective

1) Initialize DC power flow = run steady state solution
2) Initialize AC power flow = run load flow solution



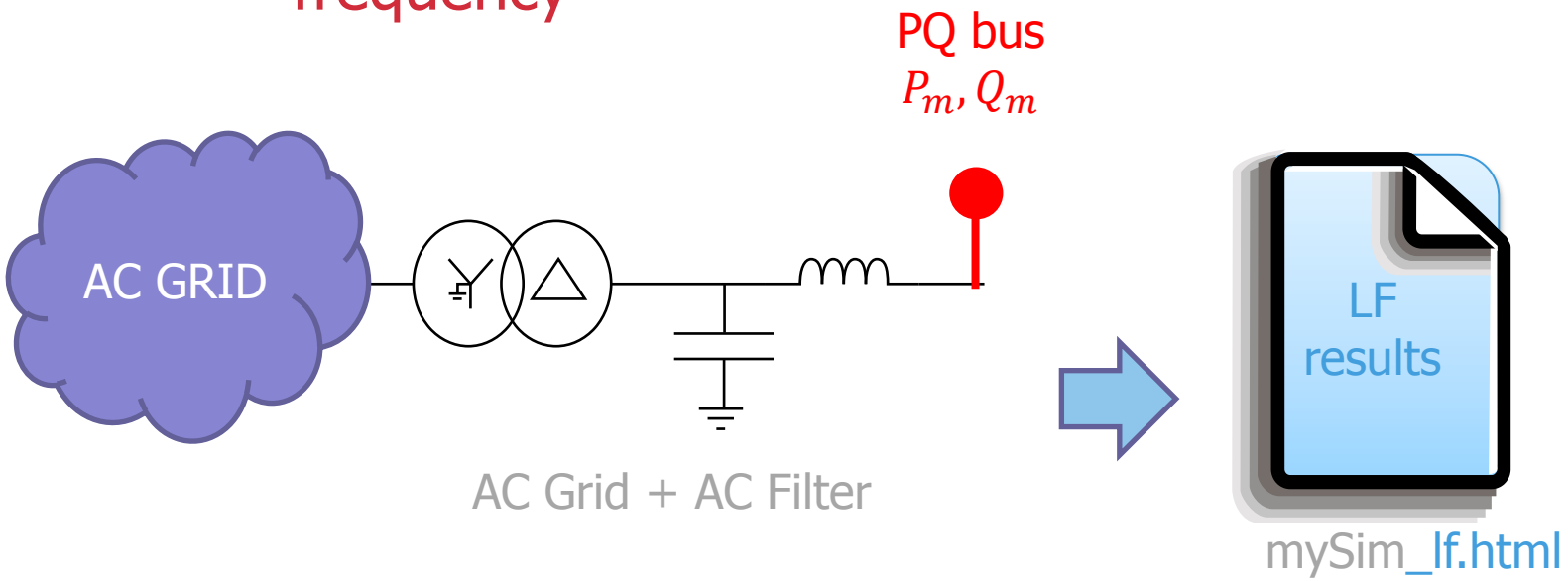
DC part initialization

1) Use ideal DC sources (Voltage & Current)
2) Run steady state solution
3) Steady state results are stored in html file at DC frequency

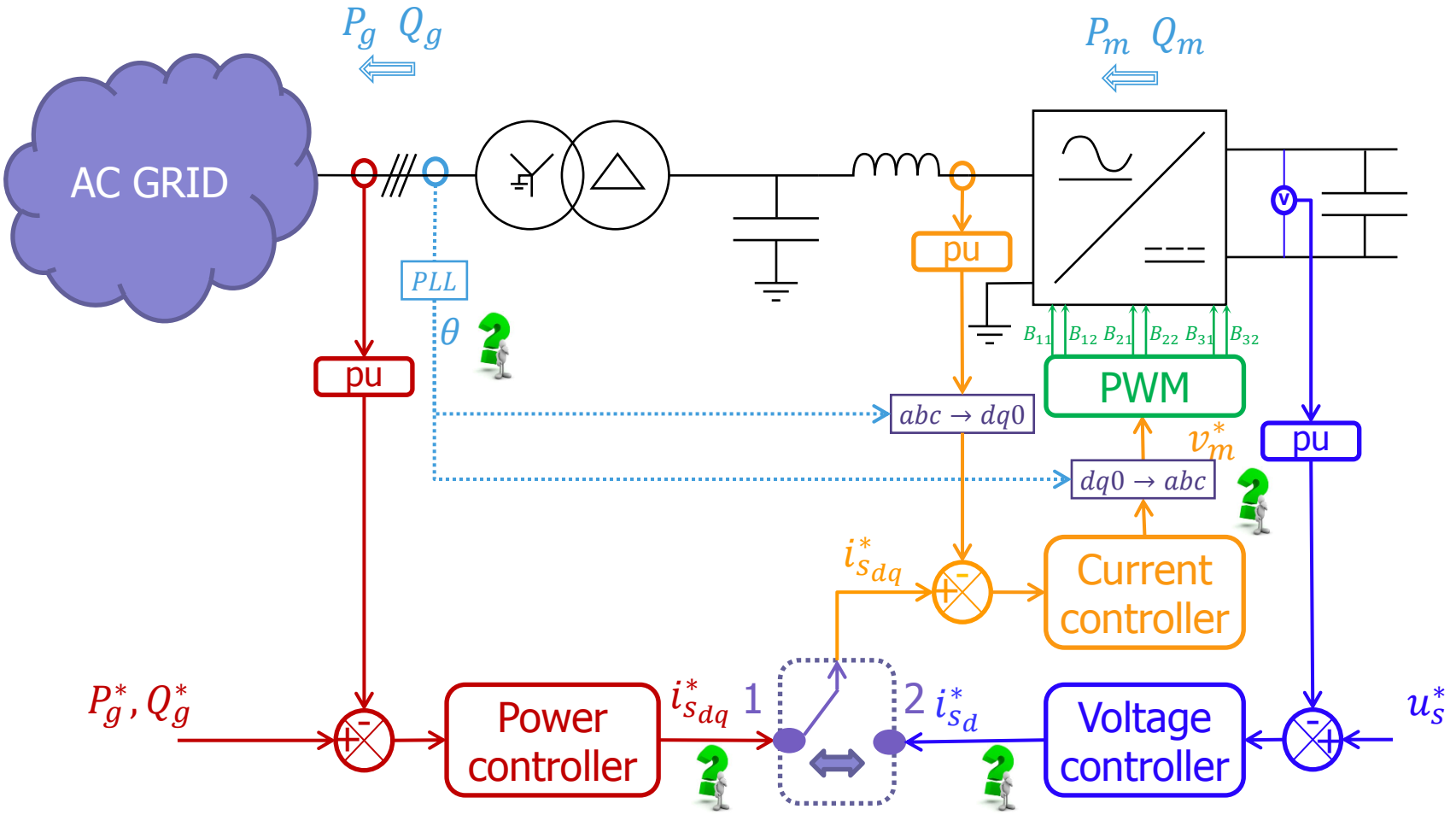


AC part initialization

1) Use Load Flow busses
2) Run Load Flow solution
3) Load Flow results are stored in a html file at AC frequency

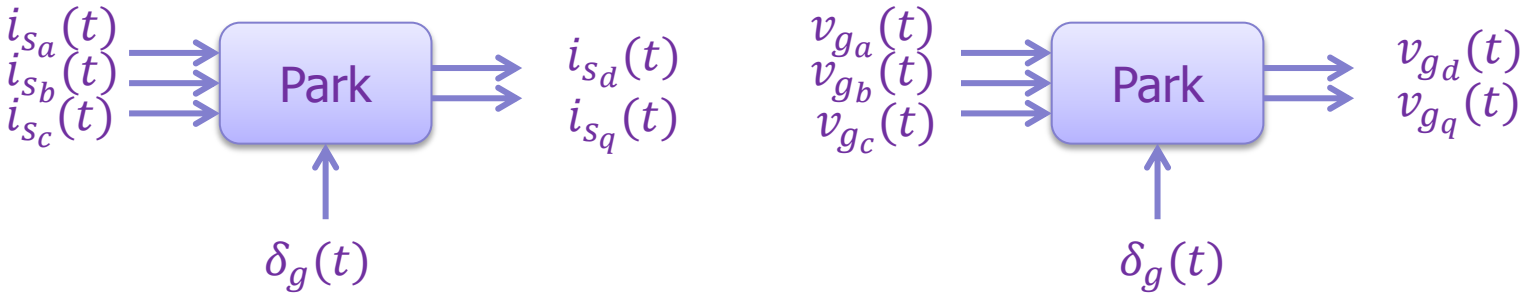


Initialization: Control part (1)

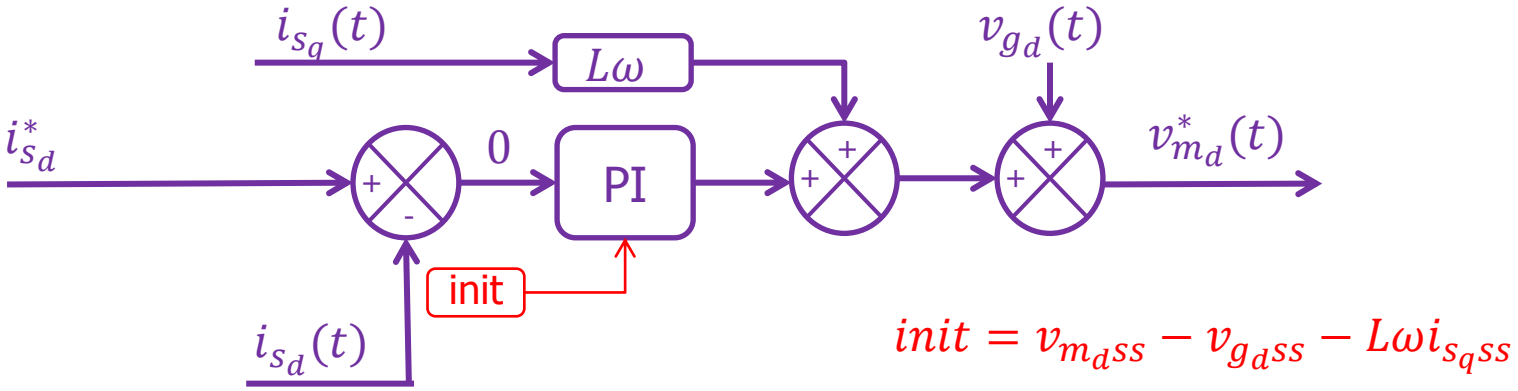


Initialization: Control part (ex: current controller)

Measures & transformations



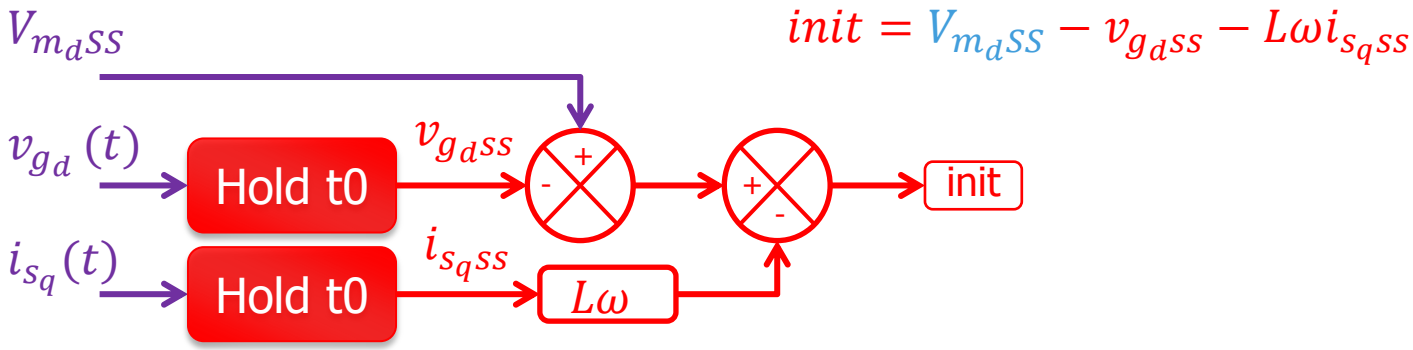
Example : Current controller



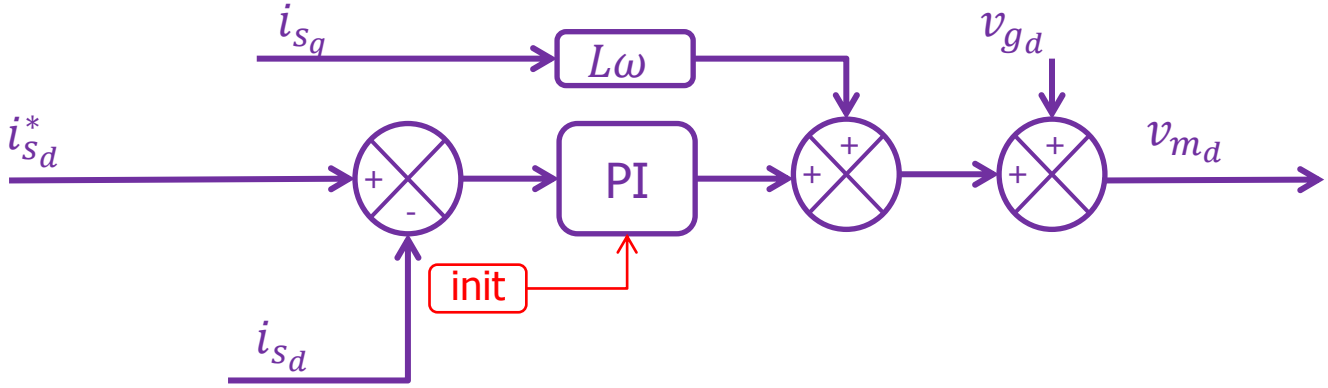
$$init = v_{m_d ss} - v_{g_d ss} - L\omega i_{s_q ss}$$

Initialization: Control part (ex: current controller)

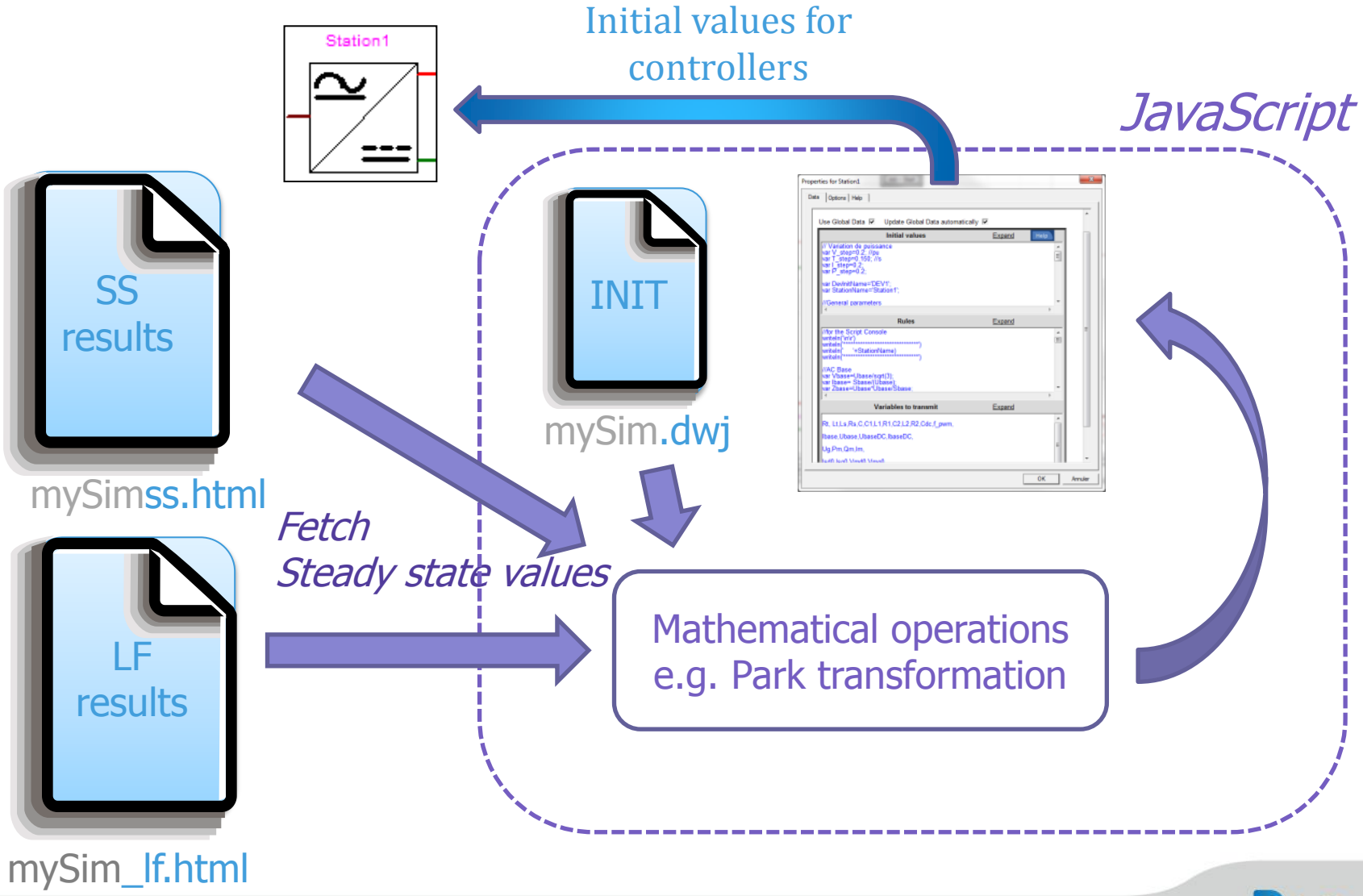
Initialization block diagram



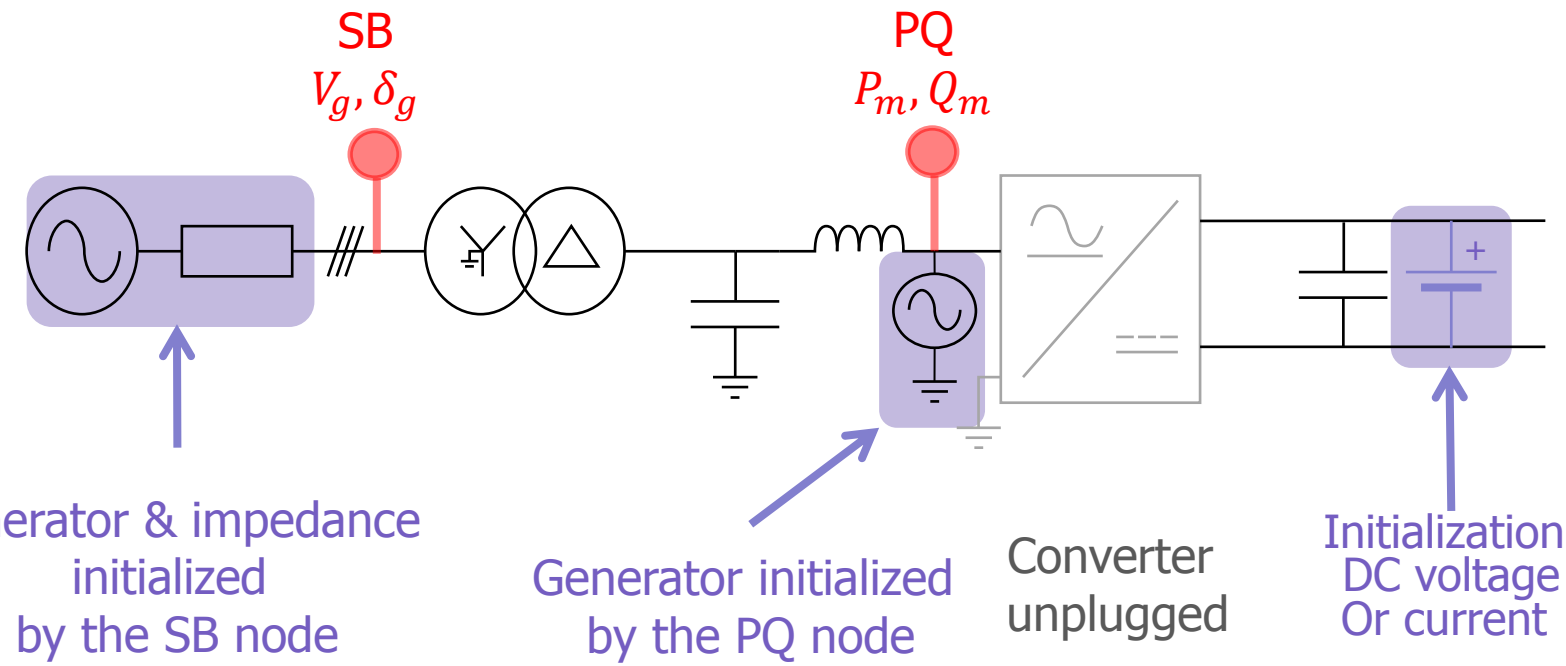
Current controller



Initialization: Control part



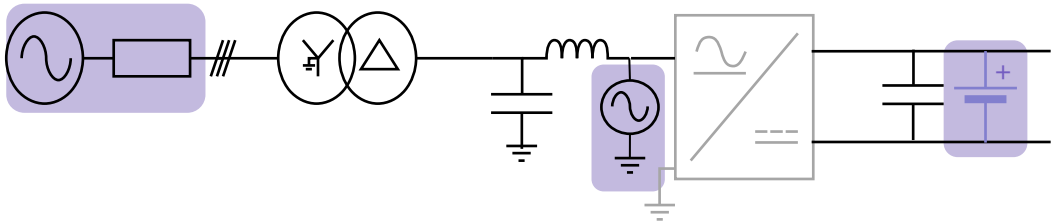
Starting simulation



Transition initialization/simulation

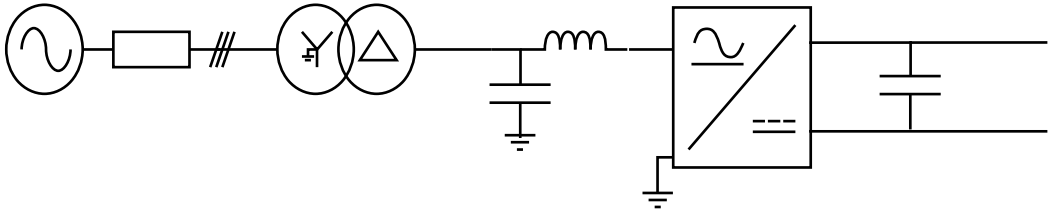
t=0 (steady state solution)

Converter unplugged



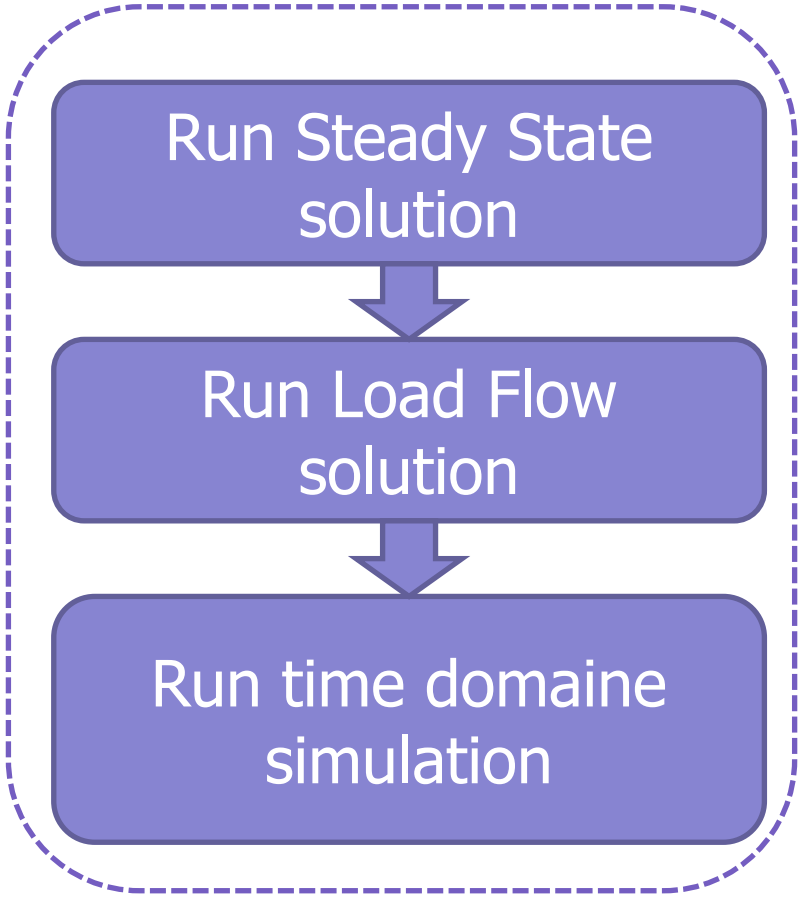
t>0

Converter plugged



- Ideal switches are used between 2 configurations
- Change before the first calculation step

Initialisation methodology on AC/DC Simulation

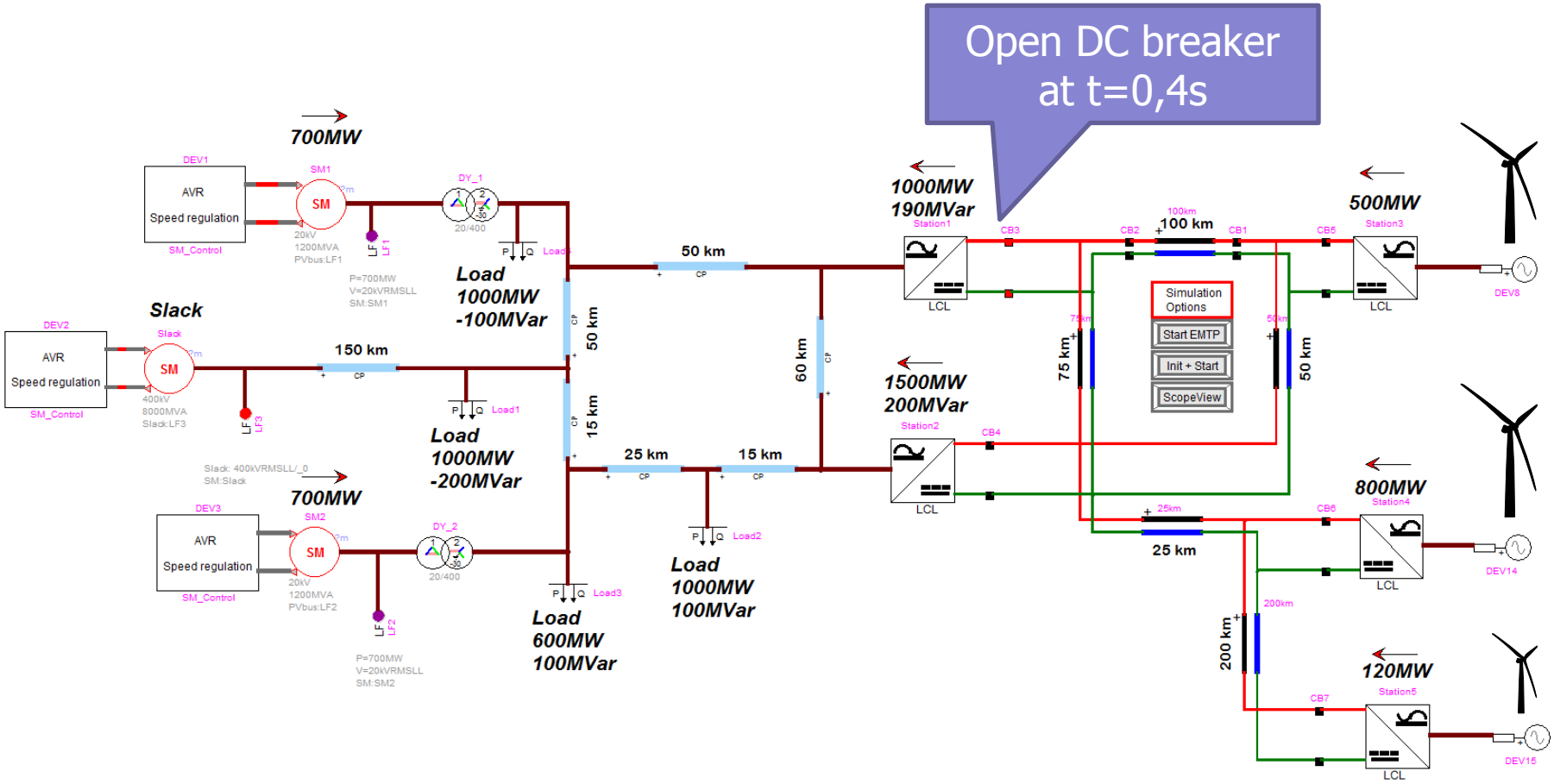


- Initiaze DC grid

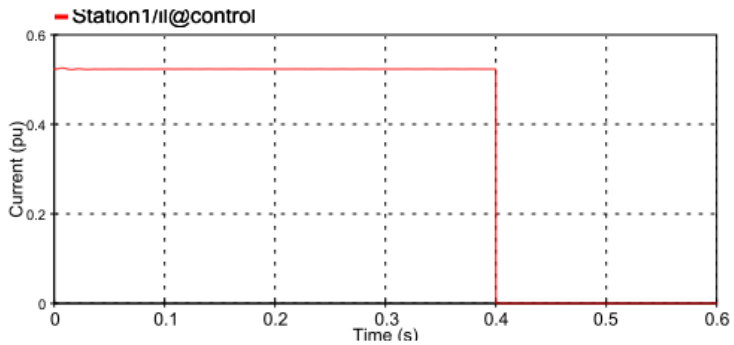
- Initialize AC grid & Control

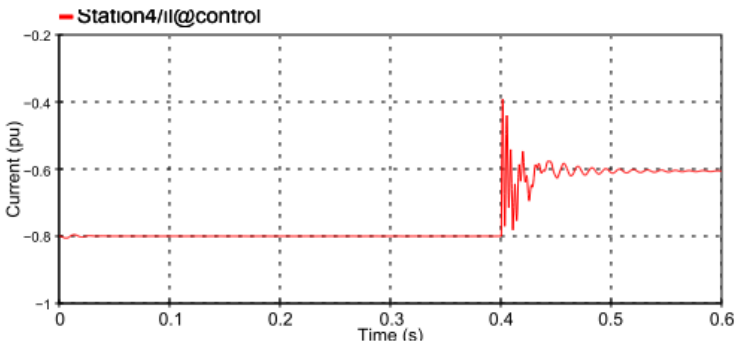
- Start from Load flow solution
- Start from Steady state
- Time domaine simulation response

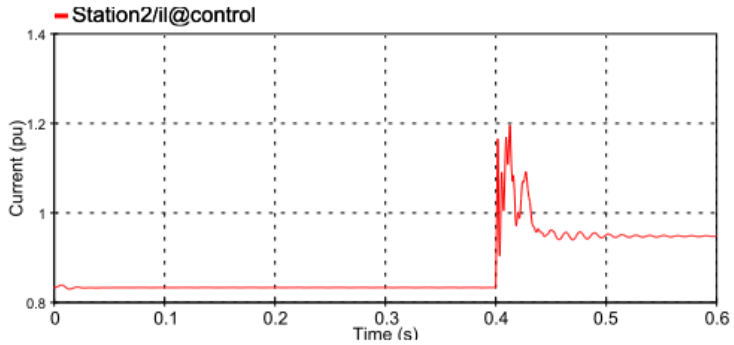
Results

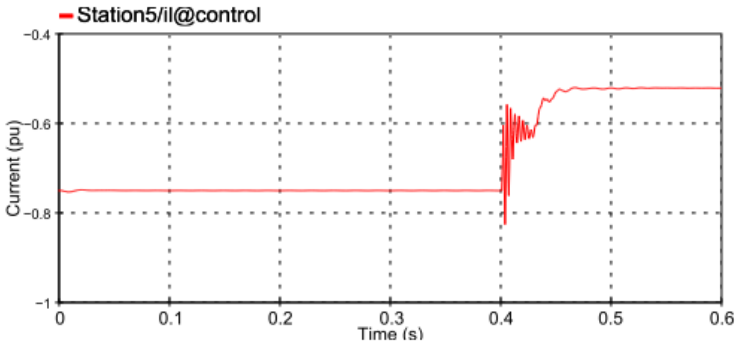

Open DC breaker at t=0,4s
700MW
DEV1
AVR
Speed regulation
SM_Control
SM1
SM
20kV
1200MVA
PVbus:LF1
P=700MW
V=20kVRMSLL
SM:SM1
LF1
DY_1
20/400
Load4
Load 1000MW -100MVar
Slack
DEV2
Slack
AVR
Speed regulation
SM_Control
SM
400kV
8000MVA
Slack:LF3
LF3
150 km
Load1
Load 1000MW -200MVar
Slack: 400kVRMSLL/_0
SM:Slack
700MW
DEV3
AVR
Speed regulation
SM_Control
SM2
SM
20kV
1200MVA
PVbus:LF2
LF2
DY_2
20/400
P=700MW
V=20kVRMSLL
SM:SM2
Load3
Load 600MW 100MVar
50 km
50 km
15 km
25 km
15 km
60 km
Load2
Load 1000MW 100MVar
1000MW 190MVar
Station1
LCL
CB3
CB2
100km
100 km
CB1
CB5
500MW
Station3
LCL
DEV8
Simulation Options
Start EMTP
Init + Start
ScopeView
75 km
50 km
1500MW 200MVar
Station2
LCL
CB4
25km
25 km
CB6
800MW
Station4
LCL
DEV14
200km
200 km
120MW
CB7
Station5
LCL
DEV15

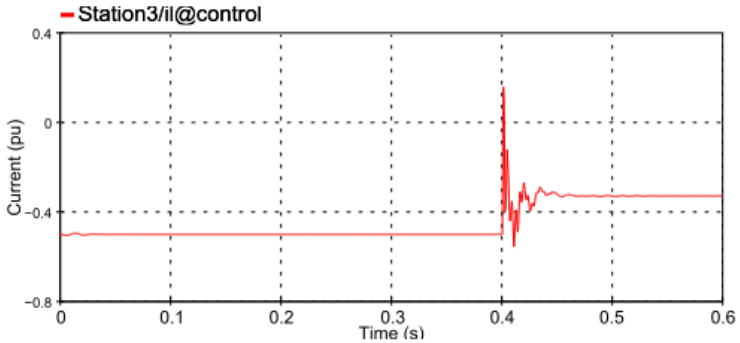
DC currents and voltage

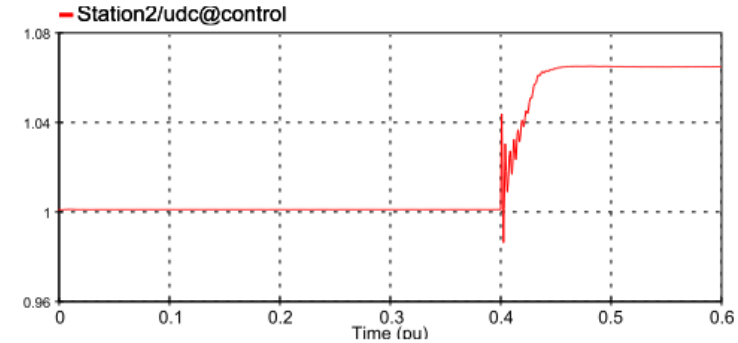




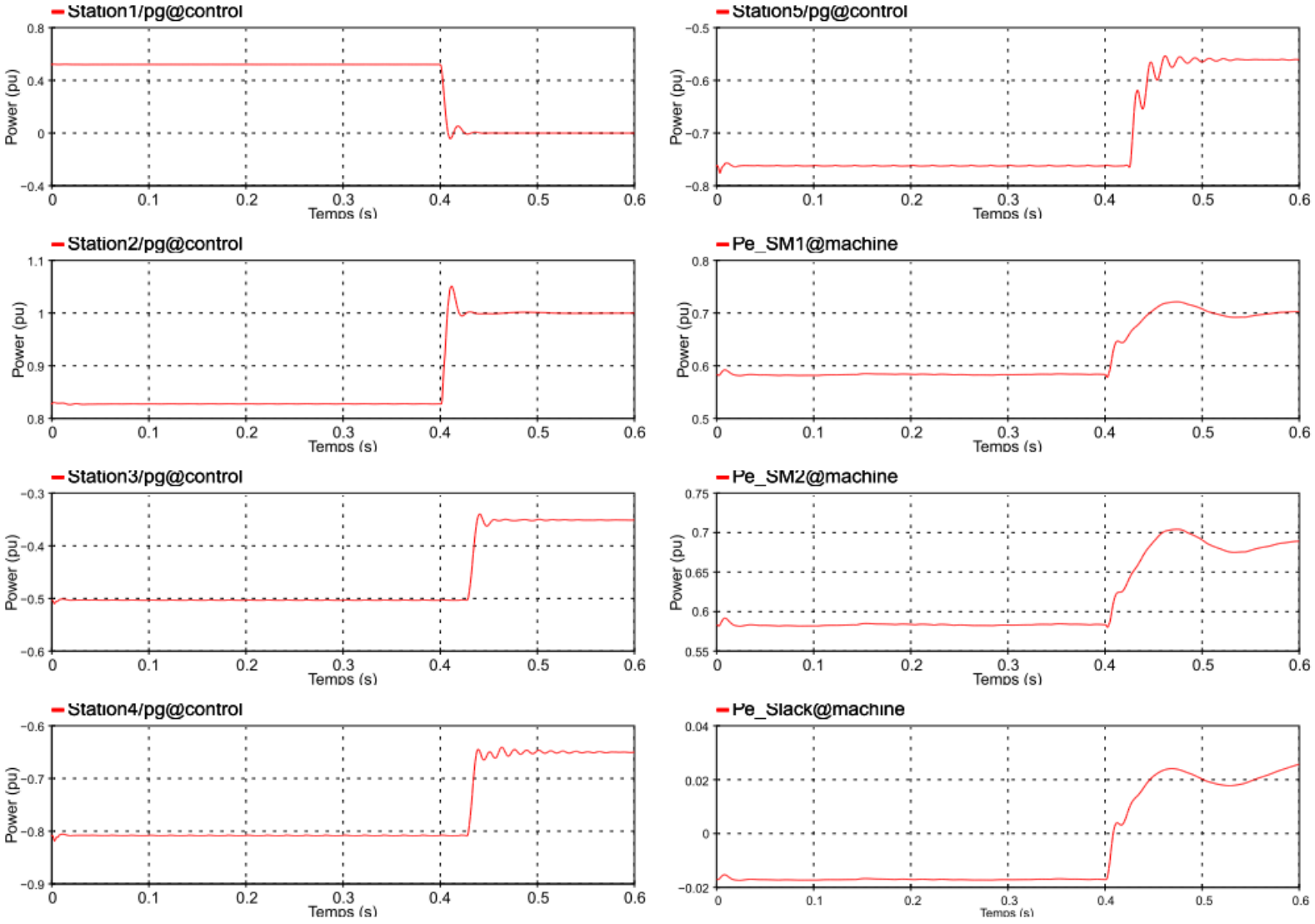




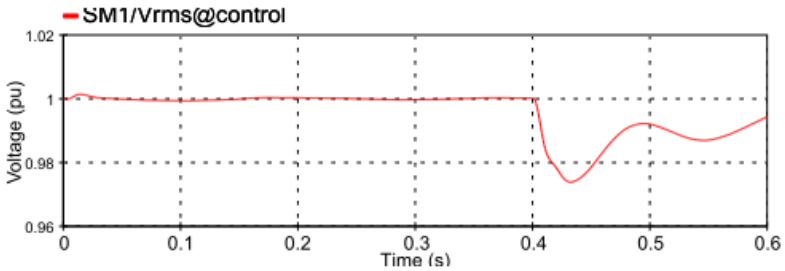


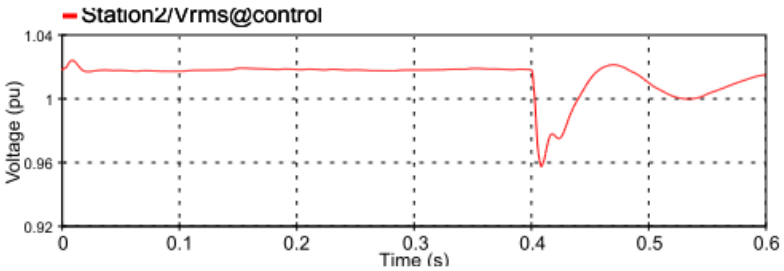


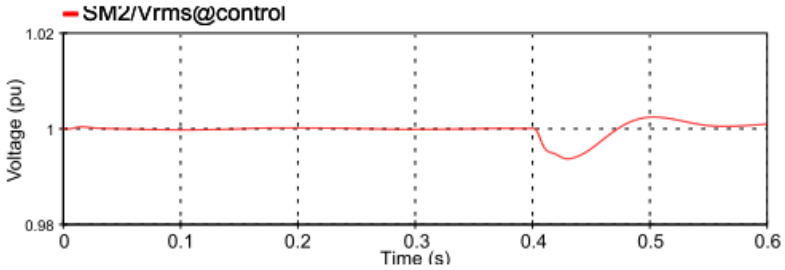
Results (Power)

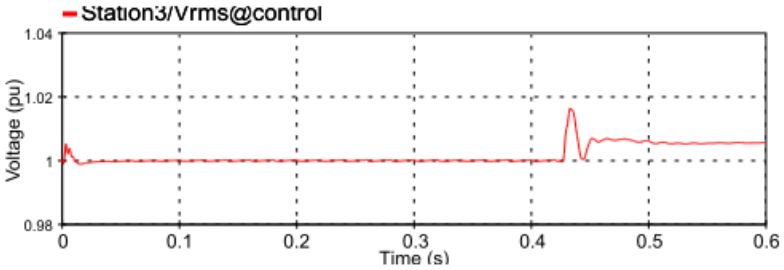


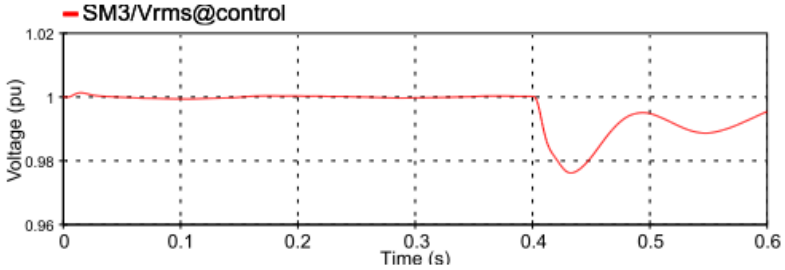
Results (AC voltage)

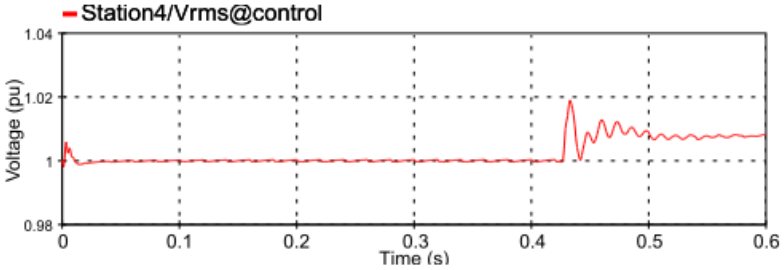


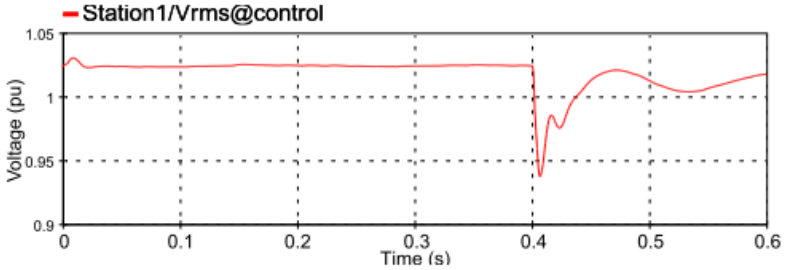


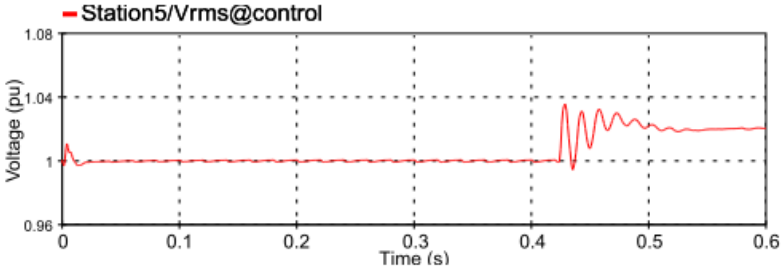












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Thank you for your attention!