Modeling and Calibrating a VSC-HVDC Model for Dynamic Simulation

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Outline

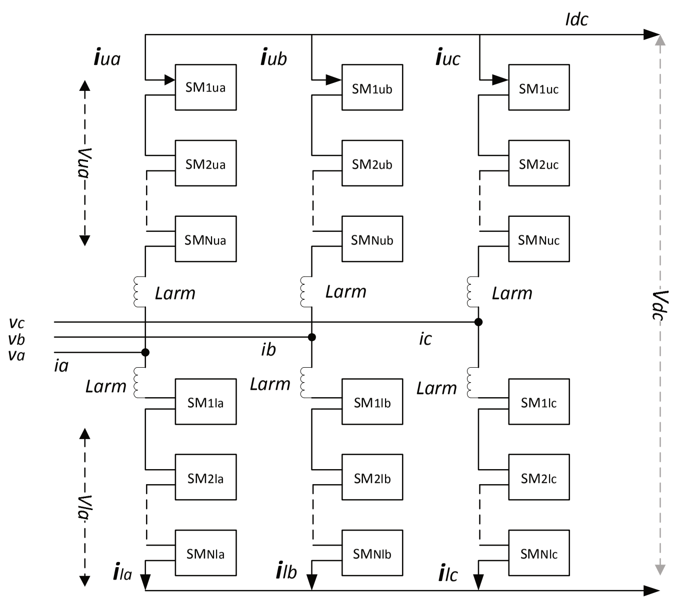
- Introduction
- VSC-HVDC Model
- Implementation in Modelica
- SW-SW to Validation
- Parameter Calibration
- Current Research

Introduction

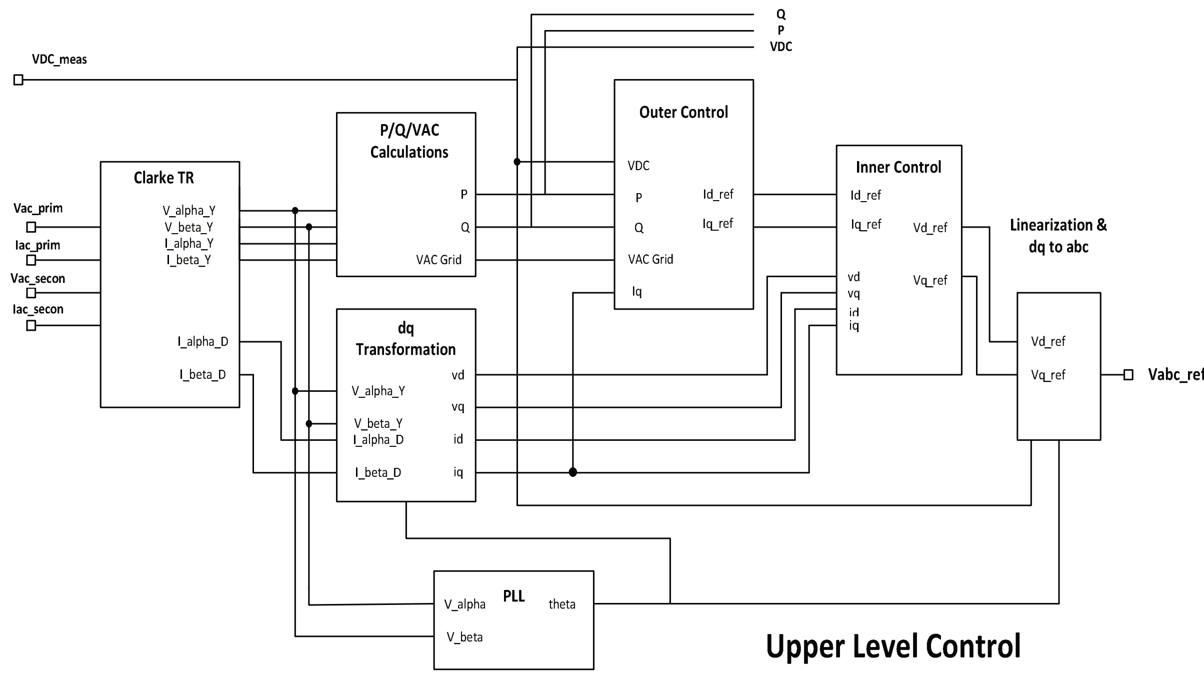
- VSC-HVDC model available in EMTP-RV
- Dynamic security assessment carried out using the iTesla[1] toolbox, requires phasor time-domain model
- One VSC-HVDC AVM model for phasor time-domain simulation is implemented in Modelica
- Control gain parameters are calibrated using RaPId toolbox

[1] http://www.itesla-project.eu/

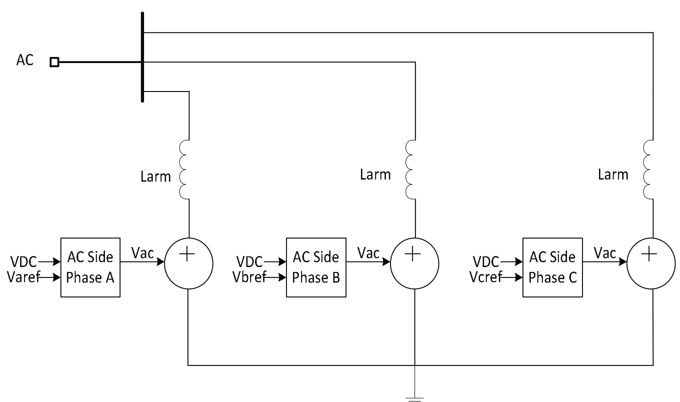
VSC-HVDC Model



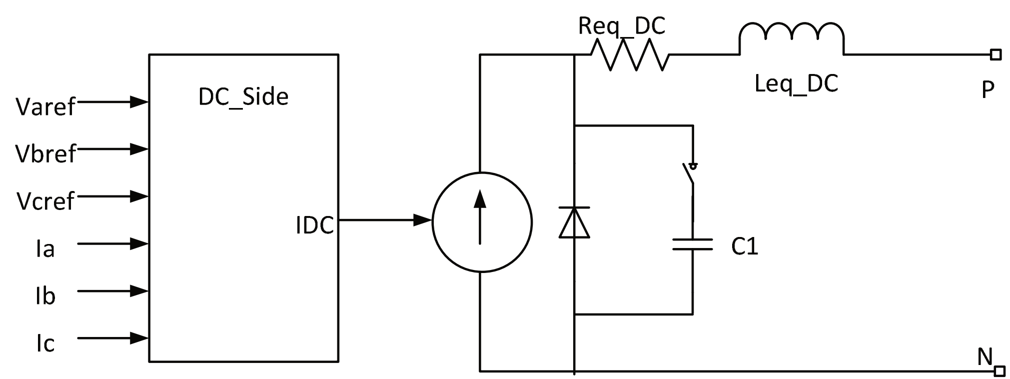
MMC Topology



Upper Level Control

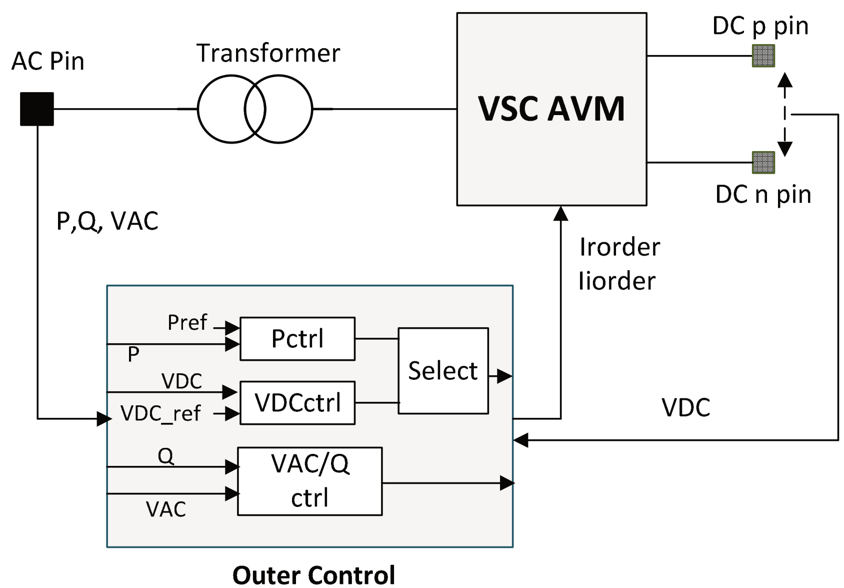


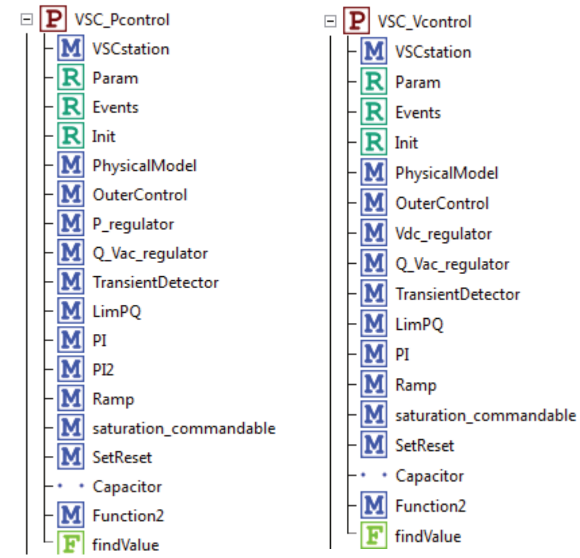
AC Side of AVM

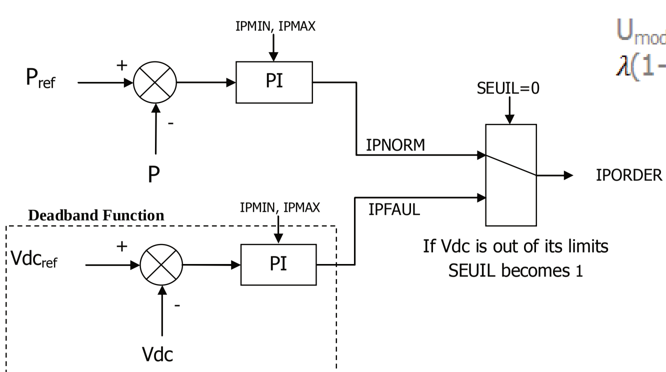


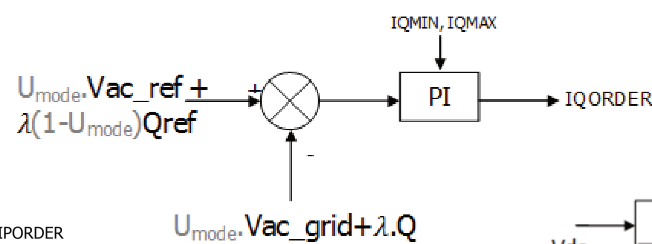
DC Side

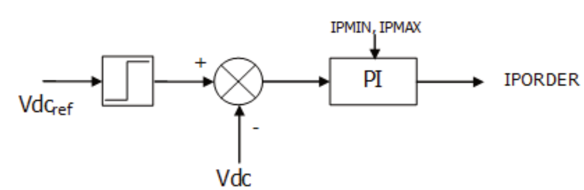
Implementation in Modelica



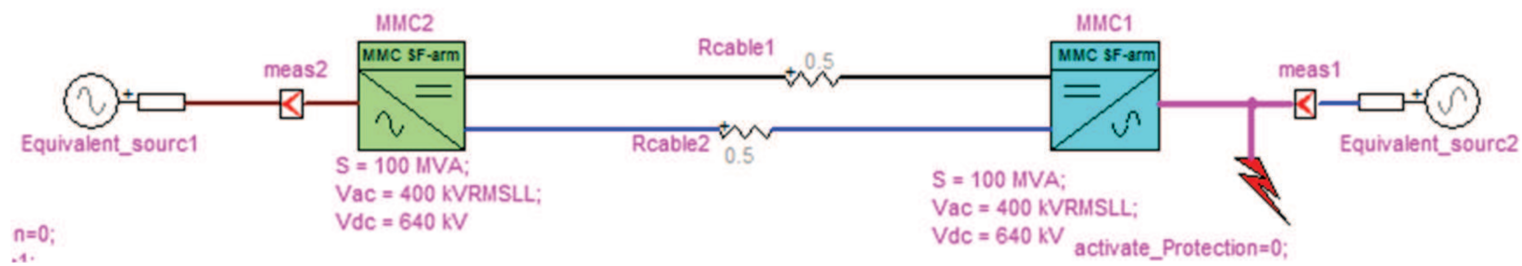








SW-SW Validation

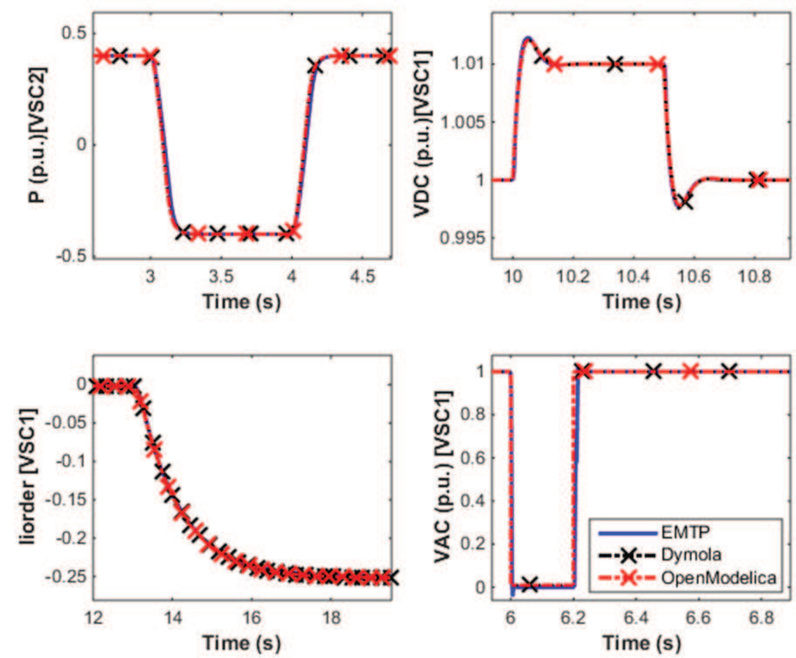


EMTP-RV Test System

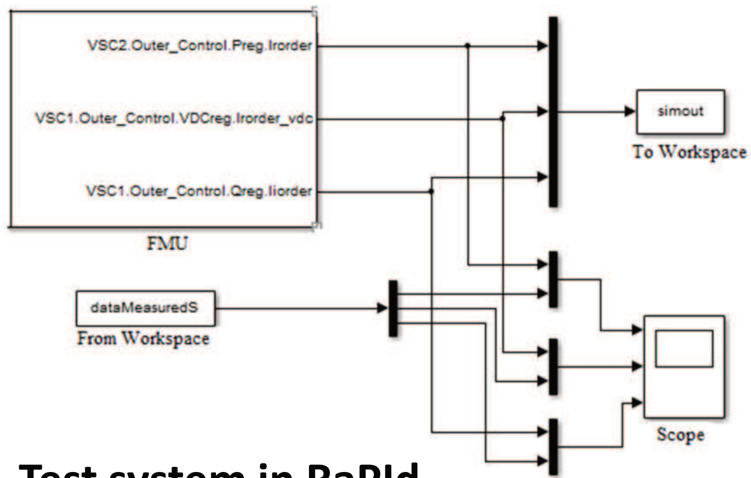
```
model Test2Inf
  Real Vpcc1;
  Real Vpcc2;
  Real P1;
  Real P2;
  // Infinite nodes with their impedances
  PowerSystems.Electrical.Buses.InfiniteBus noeud_infini1(v = 1, angle = 0);
  PowerSystems.Electrical.Buses.InfiniteBus noeud_infini2(v = 1, angle = 0);
  PowerSystems.Electrical.Branches.PwLine line1(R = 0, X = 0.01, G = 0, B = 0);
  PowerSystems.Electrical.Branches.PwLine line2(R = 0, X = 0.01, G = 0, B = 0);
  // Fault
  PowerSystems.Electrical.Events.PwFault Fault(R = 0, X = 0.0001, t1 = 6, t2 = 6.
  // DC Link with Rdc in pu_dc determined with SNref(modelica)=100MVA and Vdc=2*3
  Modelica.Electrical.Analog.Basic.Resistor resistor1(R = 0.00024);
  Modelica.Electrical.Analog.Basic.Ground ground1;
  // HVDC Stations: one controls P, the other controls Vdc
  VSC_Vcontrol.VSCstation VSC1;
  VSC_Pcontrol.VSCstation VSC2;
equation
  connect(Fault.p,VSC1.pinAC);
  // DC
  connect(VSC1.pinDC1,resistor1.p);
  connect(VSC1.pinDC2,ground1.p);
  connect(VSC2.pinDC1,resistor1.n);
  connect(VSC2.pinDC2,ground1.p);
  // AC
  connect(noeud_infini1.p,line1.p);
  connect(line1.n,VSC1.pinAC);
  connect(VSC2.pinAC,line2.n);
  connect(line2.p,noeud_infini2.p);
  Vpcc1 = line1.n.vr * line1.n.vr + line1.n.vi * line1.n.vi;
  Vpcc2 = line2.n.vr * line2.n.vr + line2.n.vi * line2.n.vi;
  P1 = -(line1.n.vr * line1.n.ir + line1.n.vi * line1.n.ii);
  P2 = -(line2.n.vr * line2.n.ir + line2.n.vi * line2.n.ii);
  a
end Test2Inf;
```

VSC stations

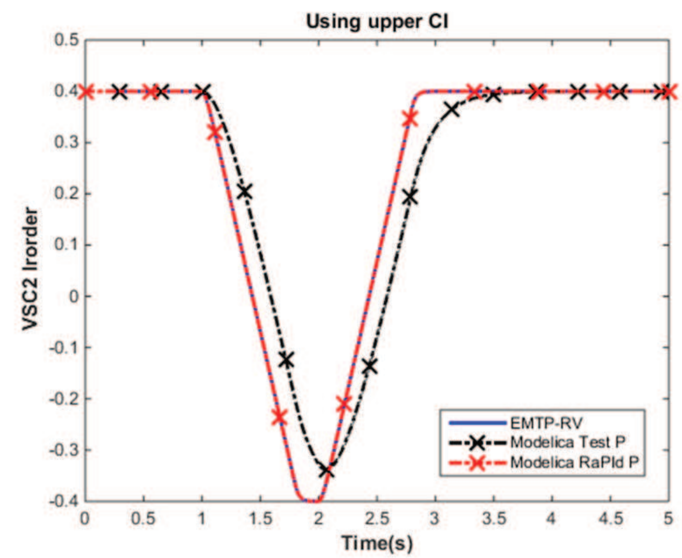
Modelica Test System



Parameter Calibration



Test system in RaPId

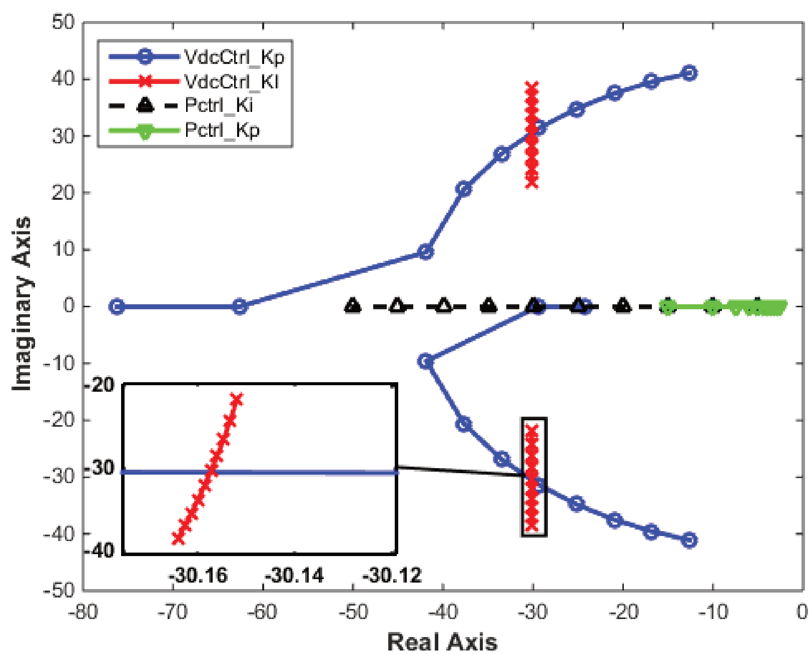


	KIVDC		KPVDC		KIP		KPP		KIQ		KPQ	
	II	SI	II	SI	II	SI	II	SI	II	SI	II	SI
Mean	891.8	834.19	26.77	26.66	31.5	31.53	0.013	0	30.06	29.32	0.076	0.263
Standard dev.	9.893	37.501	0.143	0.083	0.002	0.072	0.008	0	2.165	0.082	0.068	0.046
Variance	97.88	1406.4	0.02	0.007	8.455e-06	0.005	6.40e-05	0	4.68	0.006	.004	.002
CI (95%)	887.99 895.66	794.83 873.54	26.71 26.82	26.58 26.75	31.50 31.50	31.45 31.60	0.007 0.01	0	28.51 31.60	29.23 29.40	0.02 0.12	0.21 0.31

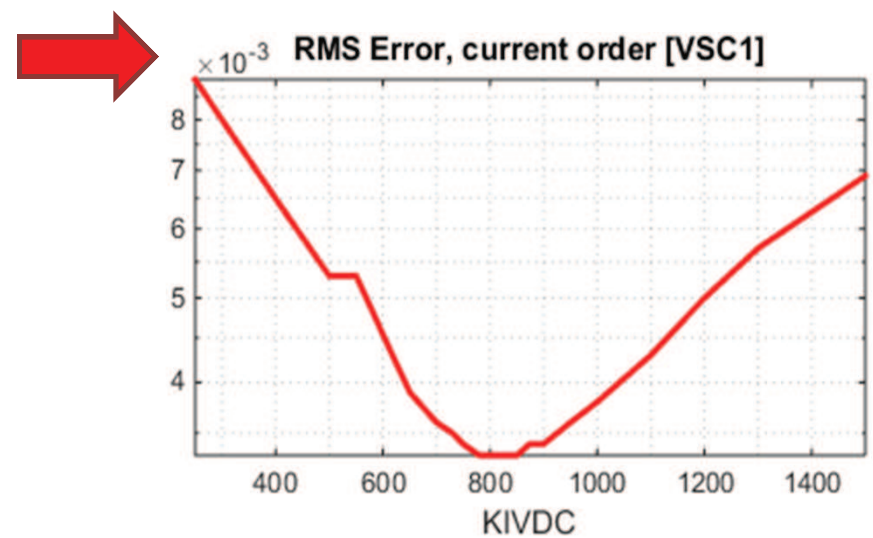
Calibration Results

Sensitivity Analysis

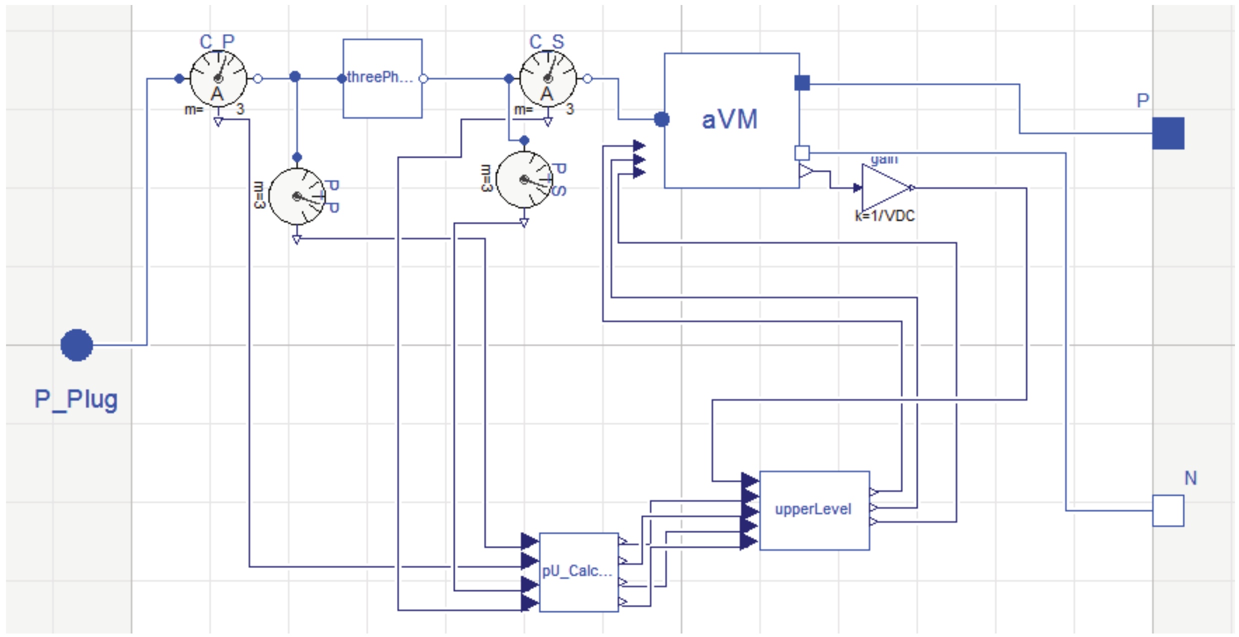
- **Linear Analysis**
  Closed-loop eigenvalues are obtained
  Independently varying the parameters of each controller

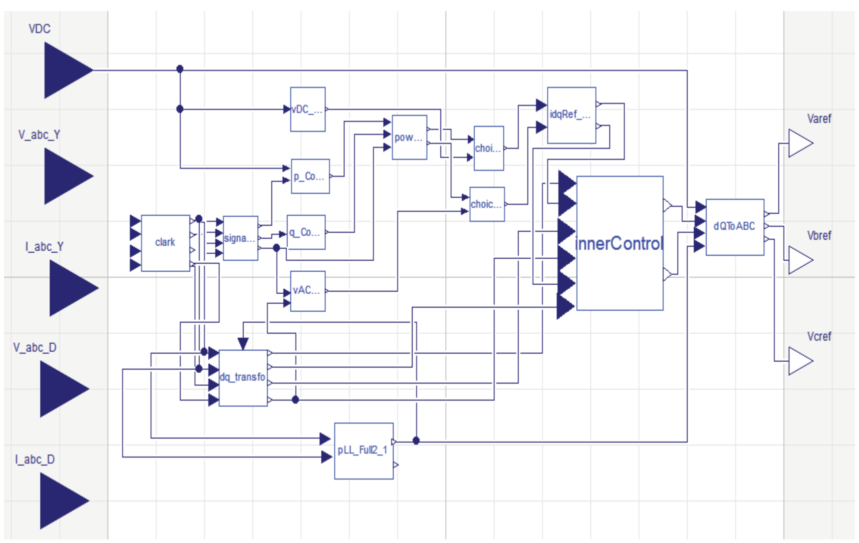


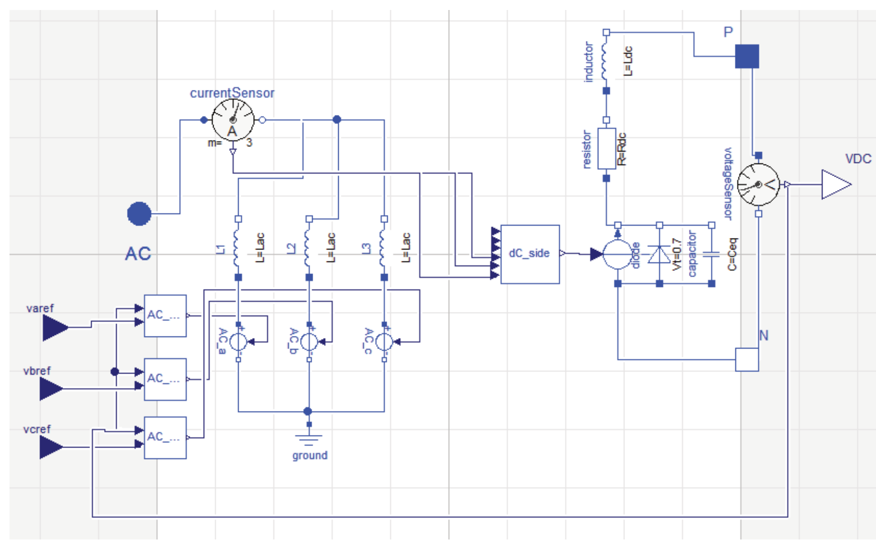
- **Non Linear analysis**
  A set of simulations were carried out using a Modelica tool with values for KIVDC [250 1500]



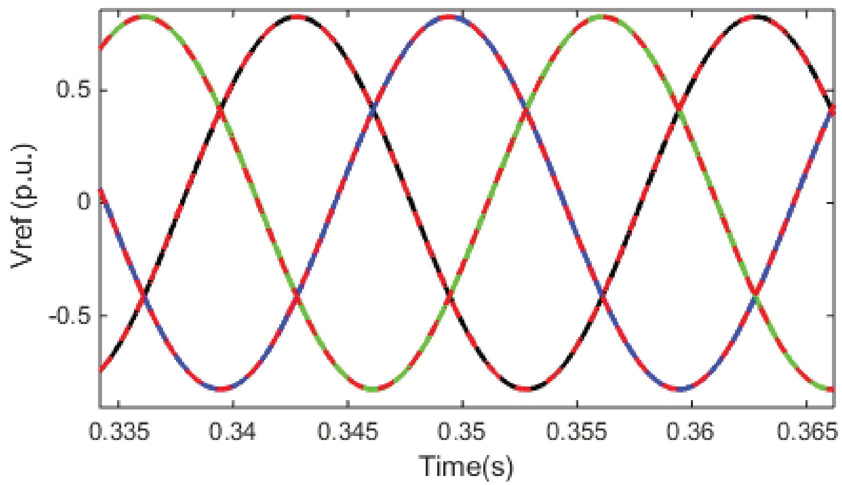
Three Phase Implementation

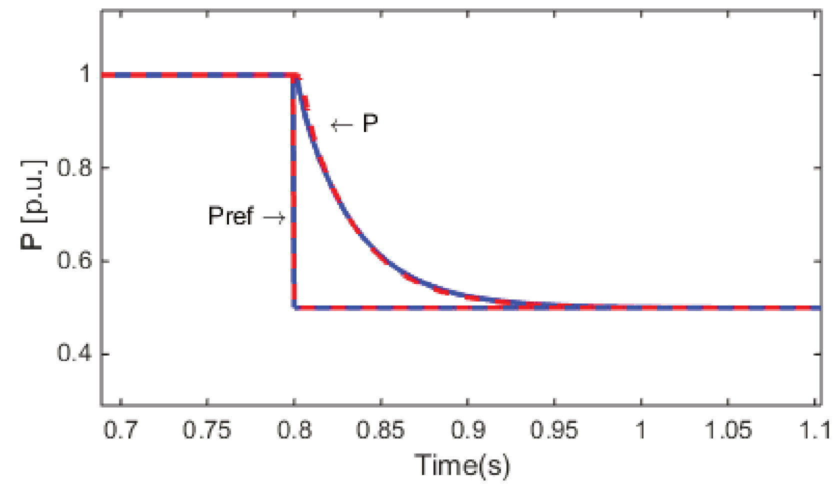


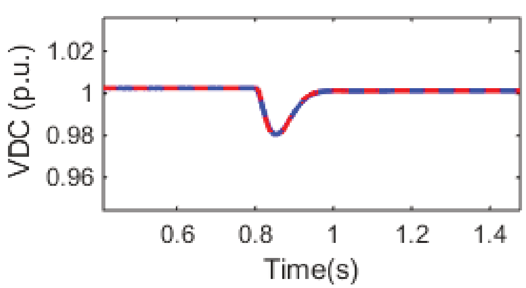


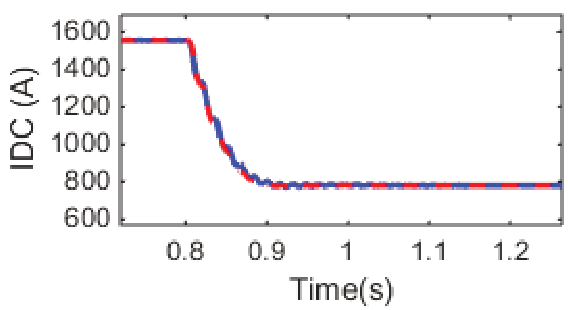


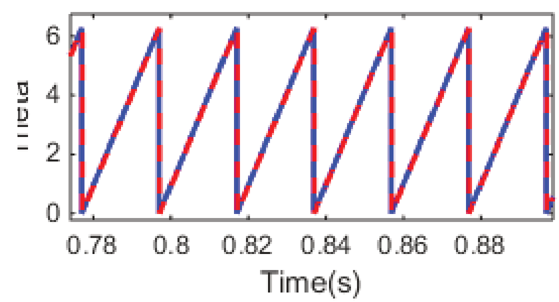
Simulation Results







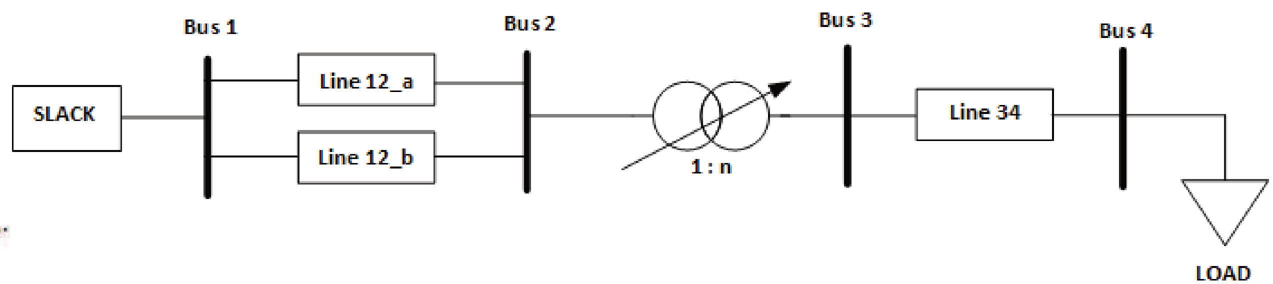


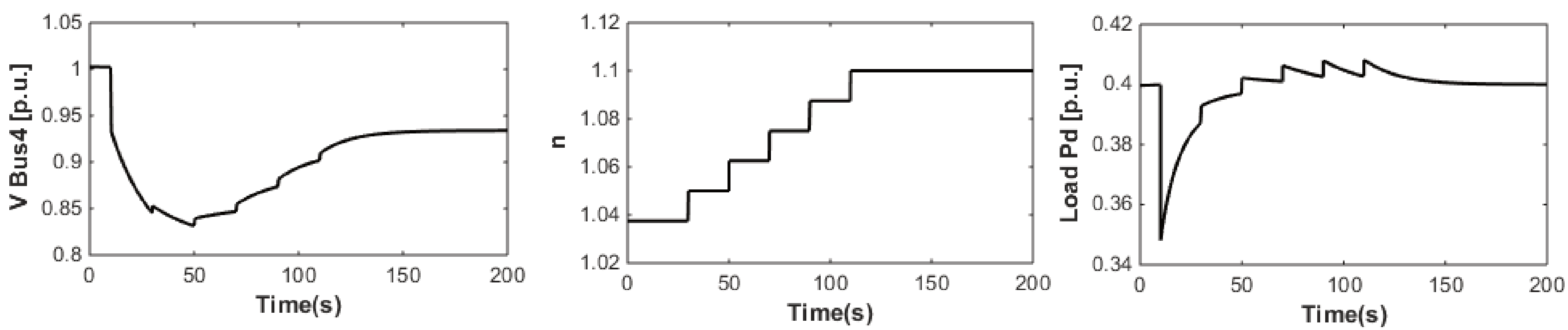


Current Research (1)

- Systematic mathematical representation of Hybrid Power System
- Hisken: Differential, Switched Algebraic and state-Reset (DSAR)

$$\dot{x} = f(x, y, z, \lambda)$$
$$\dot{z} = 0$$
$$0 = g^{(0)}(x, y)$$
$$0 = \begin{cases} g^{i^-}(x, y, z, \lambda) & y_{s,i} < 0 \\ g^{i^+}(x, y, z, \lambda) & y_{s,i} > 0 \end{cases} \qquad \text{i=1,.}$$
$$z^+ = h_j(x^-, y^-, z^-, \lambda) \quad y_{r,j} = 0 \quad j \in 1, \ldots, r$$





Questions?