LABORATORY DEMONSTRATIONS

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SiNTEF Energy Research

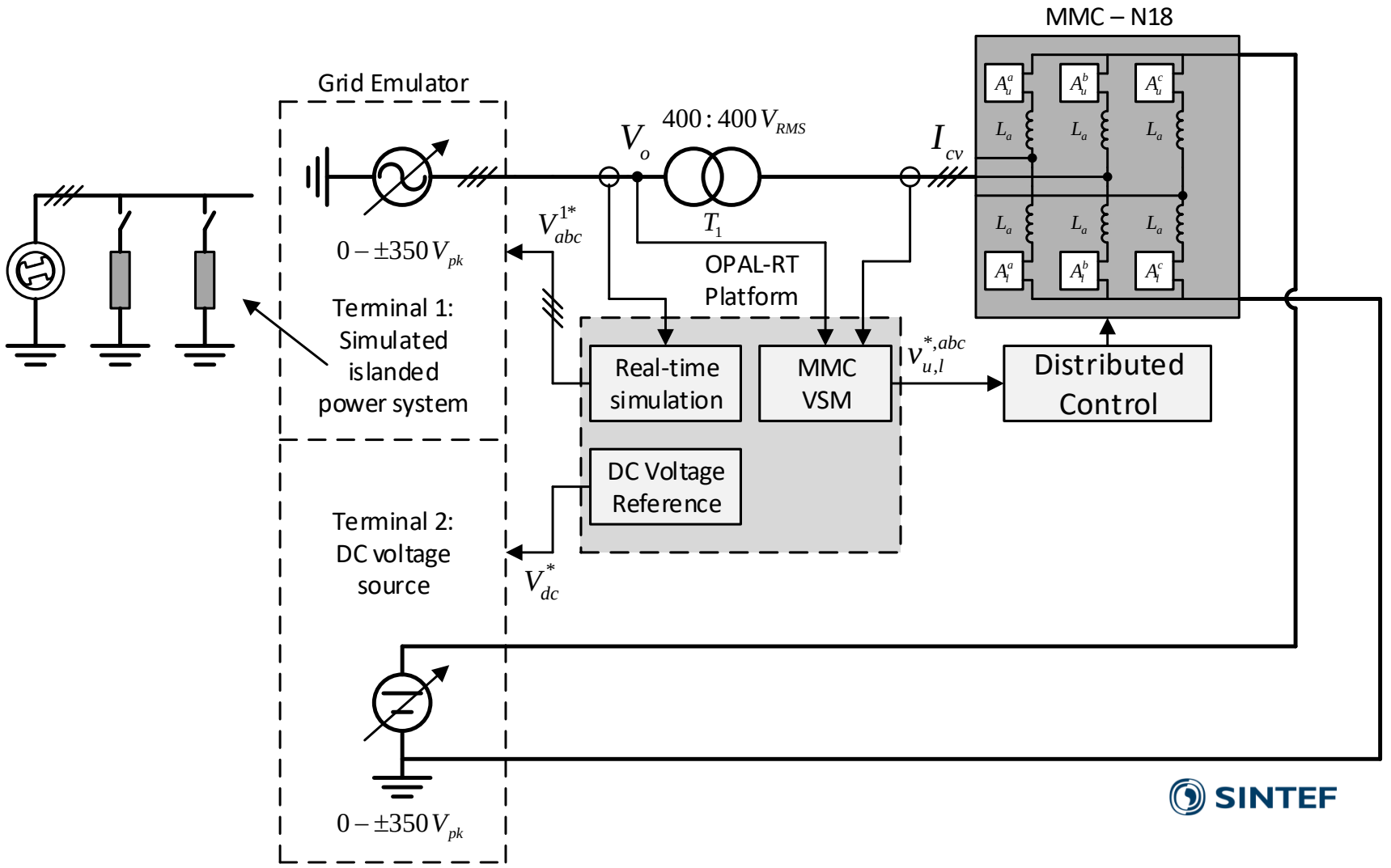
Introduction

- Inertia support to transmission system from HVDC
- Testing of a voltage regulation component ("Booster") for distribution grids
- Real time phasor simulation of a model of the Nordic transmission system

Demo 1

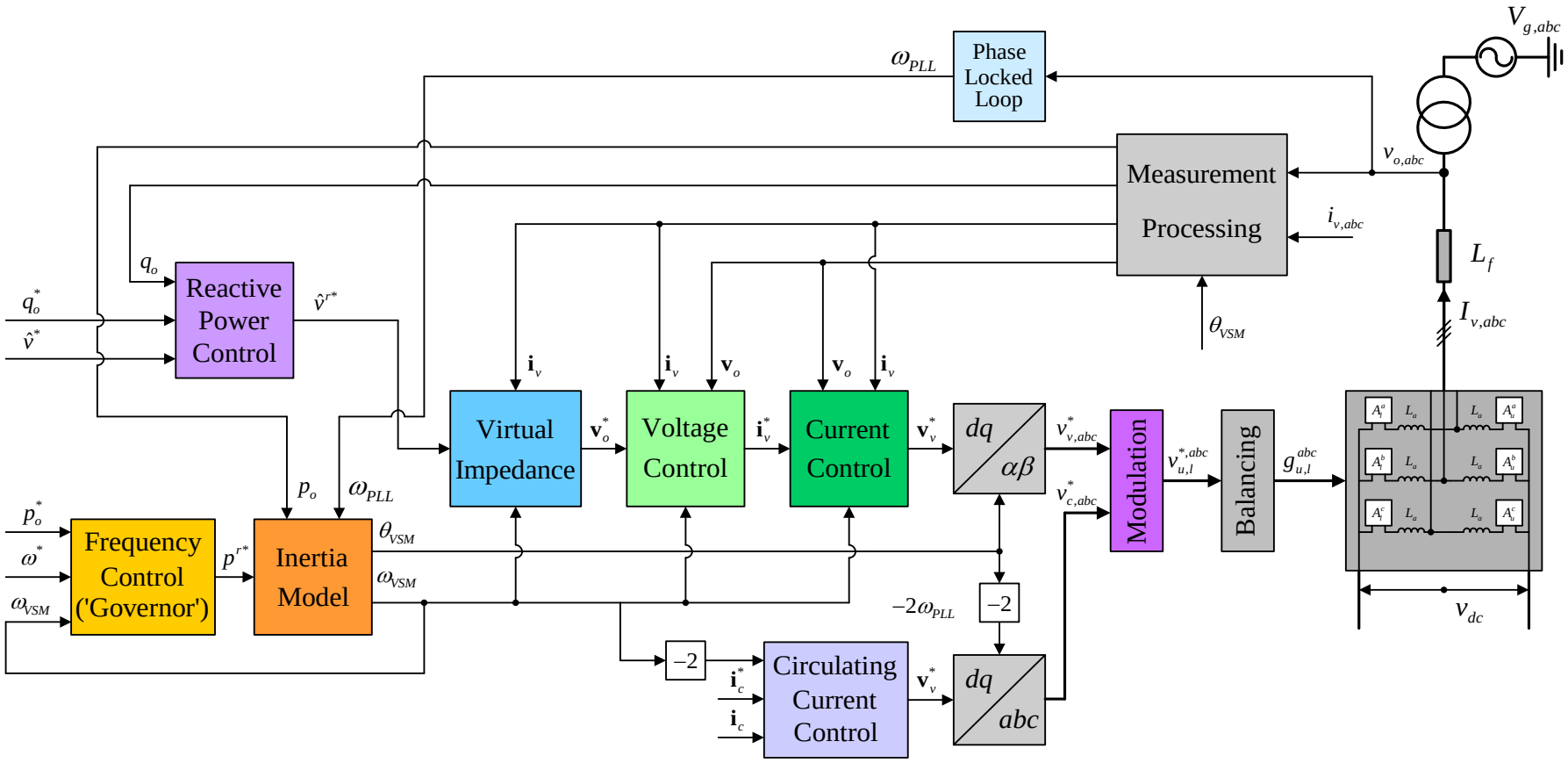
Inertia support from HVDC

- MMC connected with an emulated grid with finite inertia
  - 3 VSM implementations exposed grid frequency disturbances



MMC operated as a Voltage Controlled Virtual Synchronous Machine (VCVSM)

- The outer loop synchronous machine emulation is the same as for a 2-level VSC controlled as CCVSM
  - Inner loop ac-side current controllers are also the same as for 2-level VSC
  - No need for active damping (no LCL-filter)
- Energy controllers for each phase providing the current references for circulating current control



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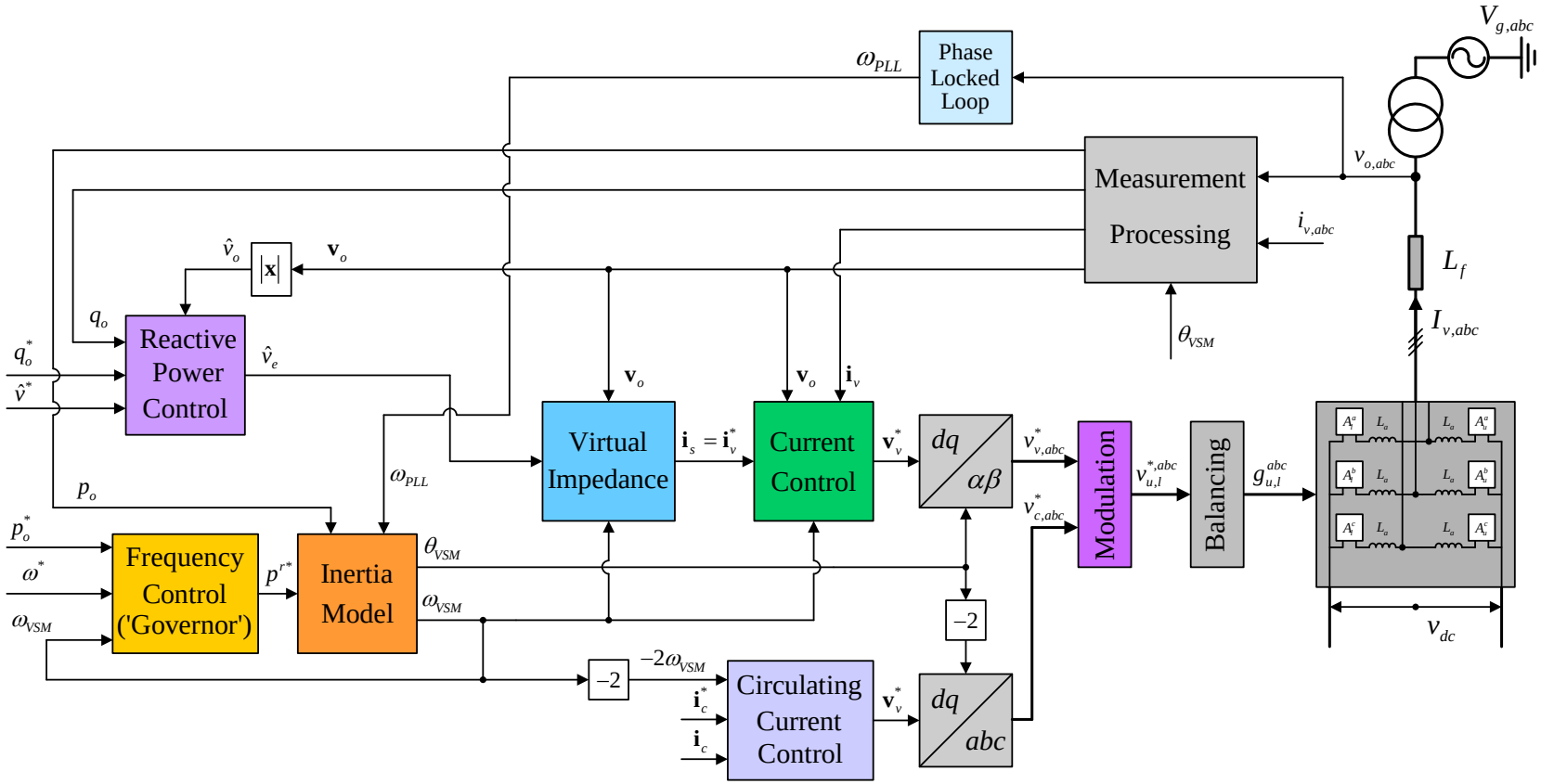
MMC operated as a Current Controlled Virtual Synchronous Machine (CCVSM)

- The outer loop synchronous machine emulation is the same as for a 2-level VSC controlled as CCVSM
  - Inner loop ac-side current controllers are also the same as for 2-level VSC
  - No need for active damping (no LCL-filter)
- Energy controllers for each phase providing the current references for circulating current control



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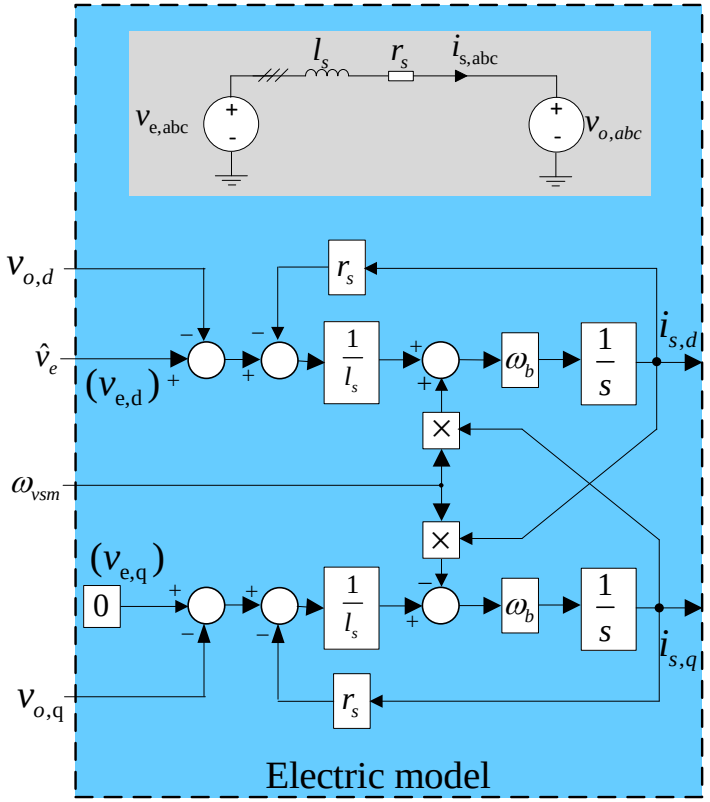
Virtual impedance - Electrical models for CCVSM

- Dynamic electrical model (DEM)

$$\mathbf{i}_s^{DEM} = \frac{\mathbf{v}_e - \mathbf{v}_o}{\left(r_s + s \cdot l_s + j \cdot \omega_{VSM} l_s\right)}$$

- Quasi-stationary electrical model (QSEM)

$$\mathbf{i}_s^{QSEM} = \frac{\mathbf{v}_e - \mathbf{v}_o}{\left(r_s + j \cdot \omega_{VSM} l_s\right)}$$



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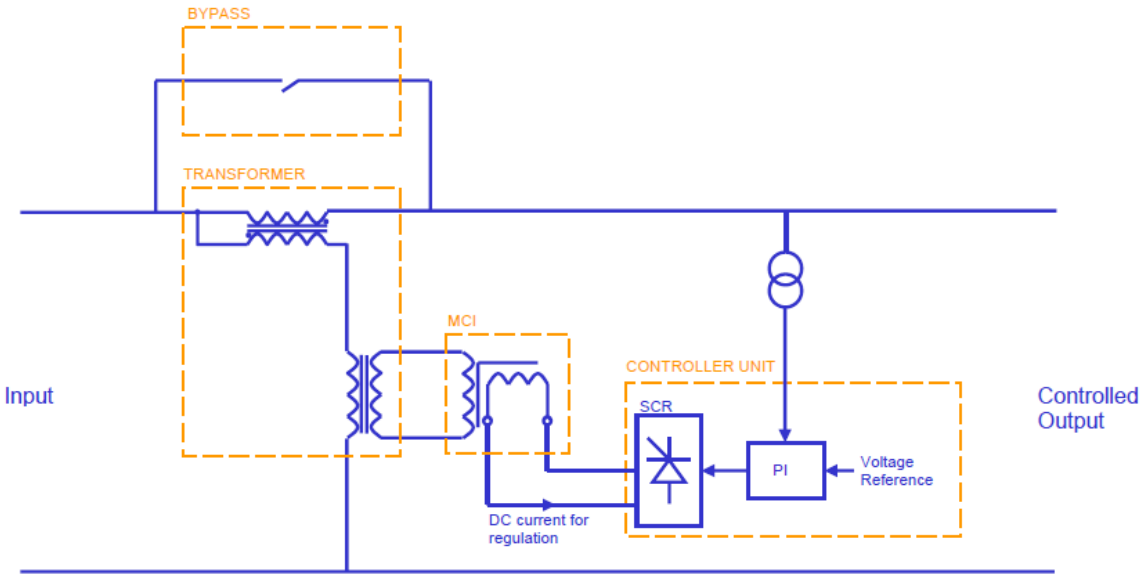
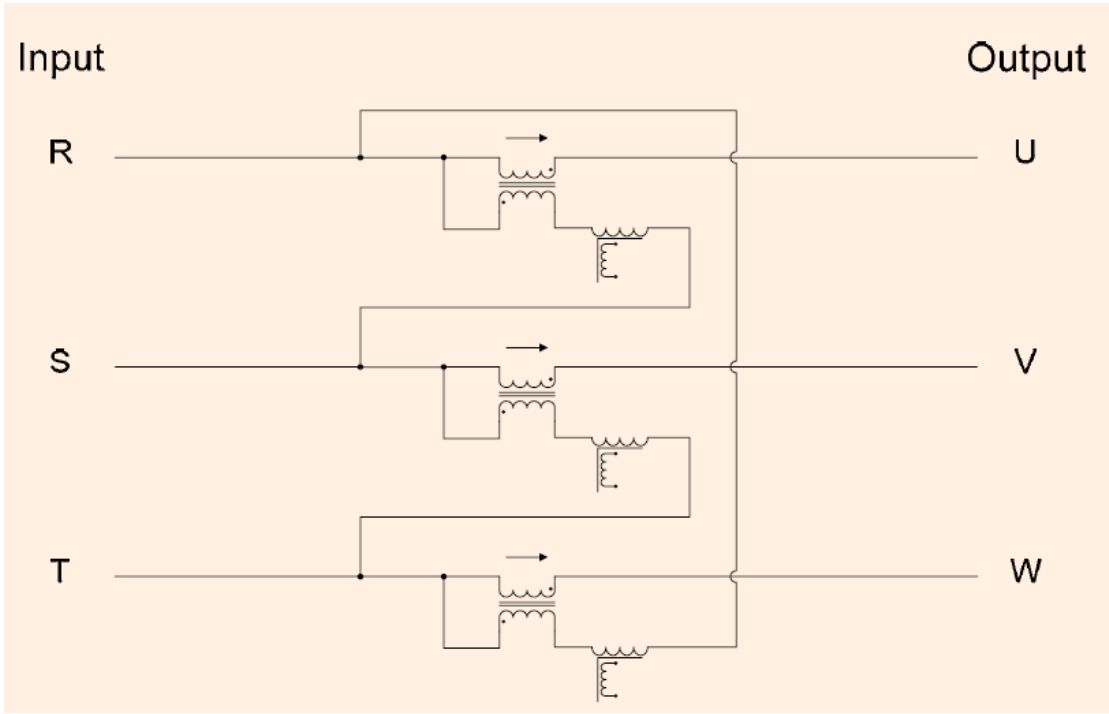
Demo 2

The Booster





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Booster spec.

Model	MVB125-230
Distribution system connection	IT
Distribution system connection Frequency [Hz]	50
Voltage [volts] (3 – phase)	230
Load, nominal [kVA]	32
Load, 6 hours, @20°C, input voltage 195 V [kVA]	50
Current nominal [A]	80
Current, 6 hours, @20°C, input voltage 195 V [A]	125
Voltage set point [V]	235
Voltage lift [%] (symmetrical loads)	0…+20
Voltage lift, voltage reduction [%] (unbalanced loads)	0…+20
Dynamic response [ms]	200
No-load loss [W]	220
Efficiency [%]	95-97
Power factor [cos j]	0,96-0,97
Total Harmonic Distortion [%]	1 to 4
Mechanical dimensions	
Width x Height x Depth [mm]	1003x1190x648
Weight [kg]	750
Cable connection [Copper mm2]	≤ 50
Oil filled [liters]	158
Enclosure oil filled	Galvanized
Features	
Bypass @ U_out ±15% or high temp	√
Handles 100% unbalanced load and maintains the voltage	50 %
Single pole short circuit capacity increased by a minimum of 60%	unchanged
No moving parts in the power circuit	√
Maintenance free	√
25 years designed lifetime	√
Quick installation < one day	√

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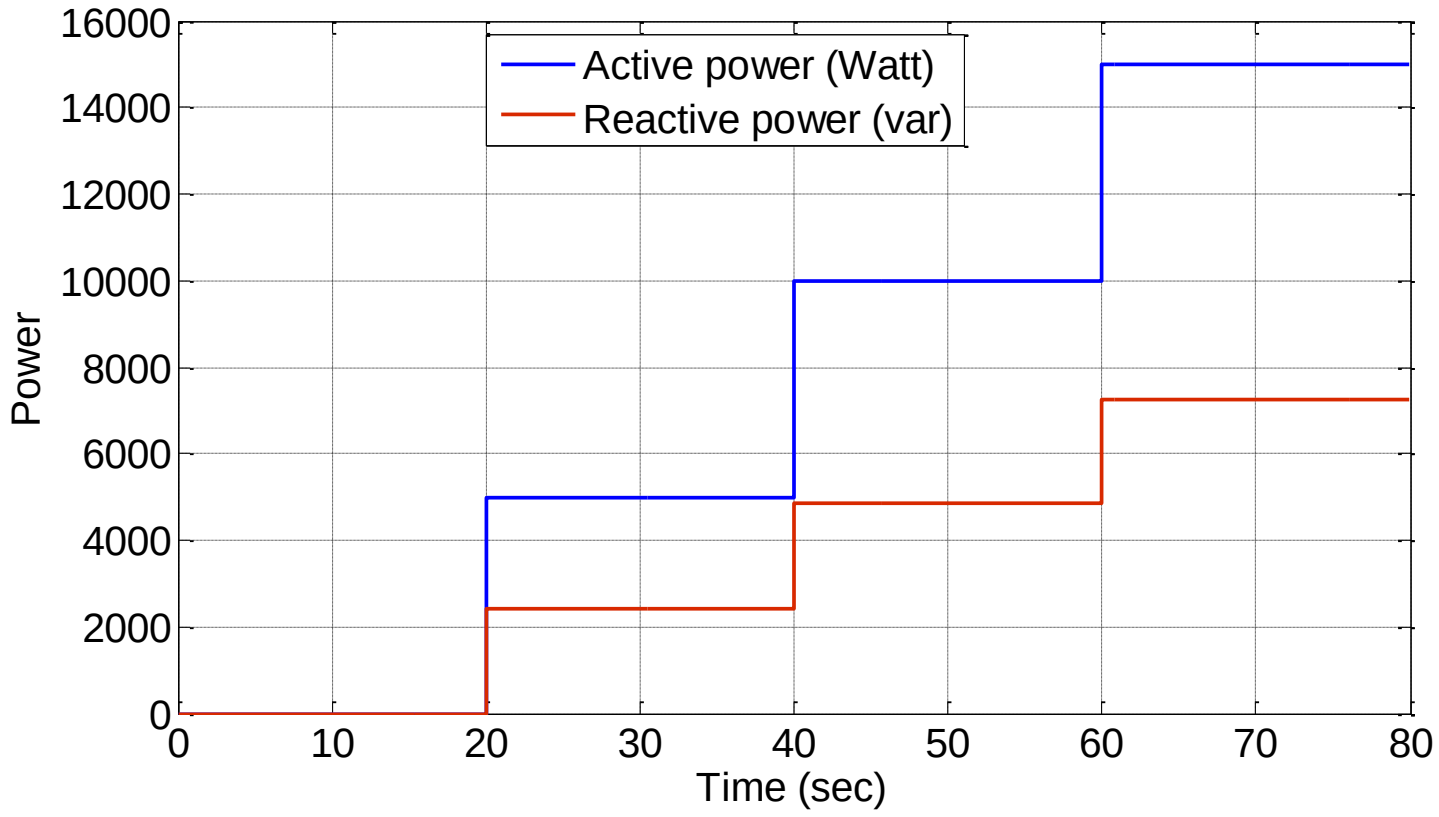
The test

(Booster capabilities under various loading scenarios)



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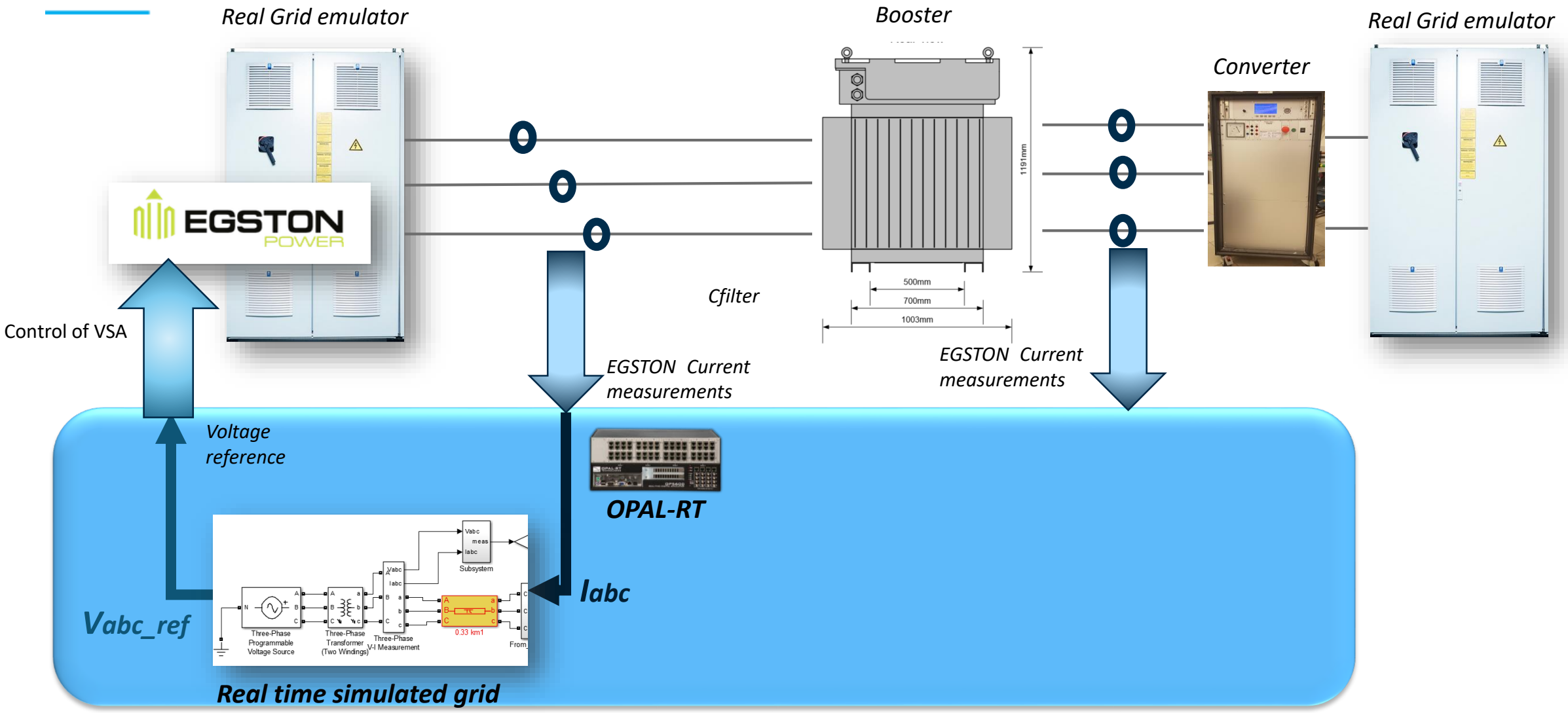
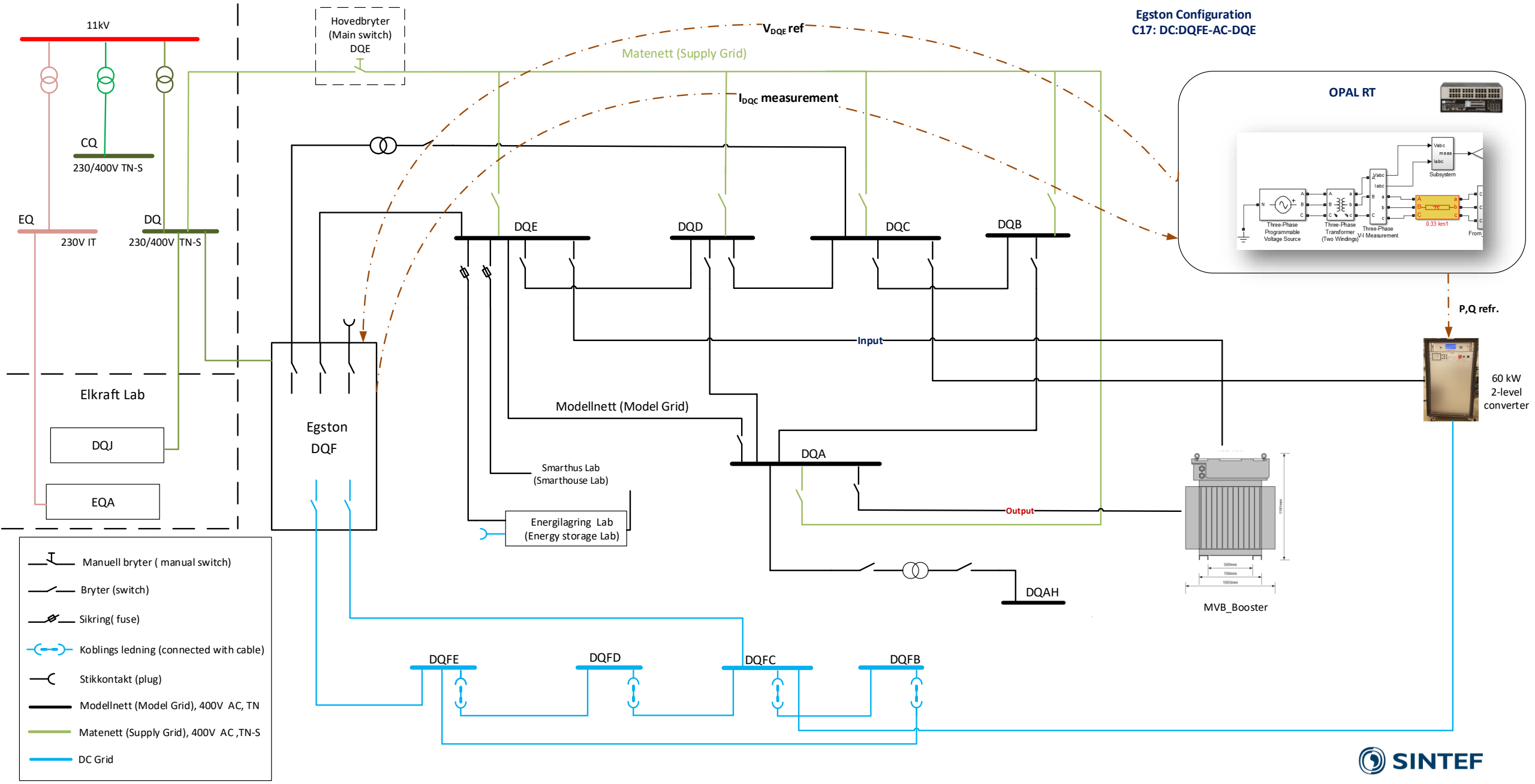
The Setup


Real Grid emulator
Booster
Real Grid emulator
Converter
EGSTON POWER
Control of VSA
Cfilter
500mm
700mm
1003mm
1191mm
EGSTON Current measurements
EGSTON Current measurements
Voltage reference
OPAL-RT
Vabc_ref
Iabc
Vabc
meas
Iabc
Subsystem
Three-Phase Programmable Voltage Source
Three-Phase Transformer (Two Windings)
Three-Phase V-I Measurement
0.33 km1
From
Real time simulated grid


11kV
Hovedbryter
(Main switch)
DQE
V_{DQE} ref
Matenett (Supply Grid)
I_{DQC} measurement
Egston Configuration
C17: DC:DQFE-AC-DQE
OPAL RT
CQ
230/400V TN-S
EQ
230V IT
DQ
230/400V TN-S
DQE
DQD
DQC
DQB
Input
P,Q refr.
60 kW
2-level
converter
Elkraft Lab
DQJ
EQA
Egston
DQF
Modellnett (Model Grid)
Smarthus Lab
(Smarthouse Lab)
Energilagring Lab
(Energy storage Lab)
DQA
Output
DQAH
MVB_Booster
DQFE
DQFD
DQFC
DQFB
Manuell bryter (manual switch)
Bryter (switch)
Sikring(fuse)
Koblings ledning (connected with cable)
Stikkontakt (plug)
Modellnett (Model Grid), 400V AC, TN
Matenett (Supply Grid), 400V AC ,TN-S
DC Grid
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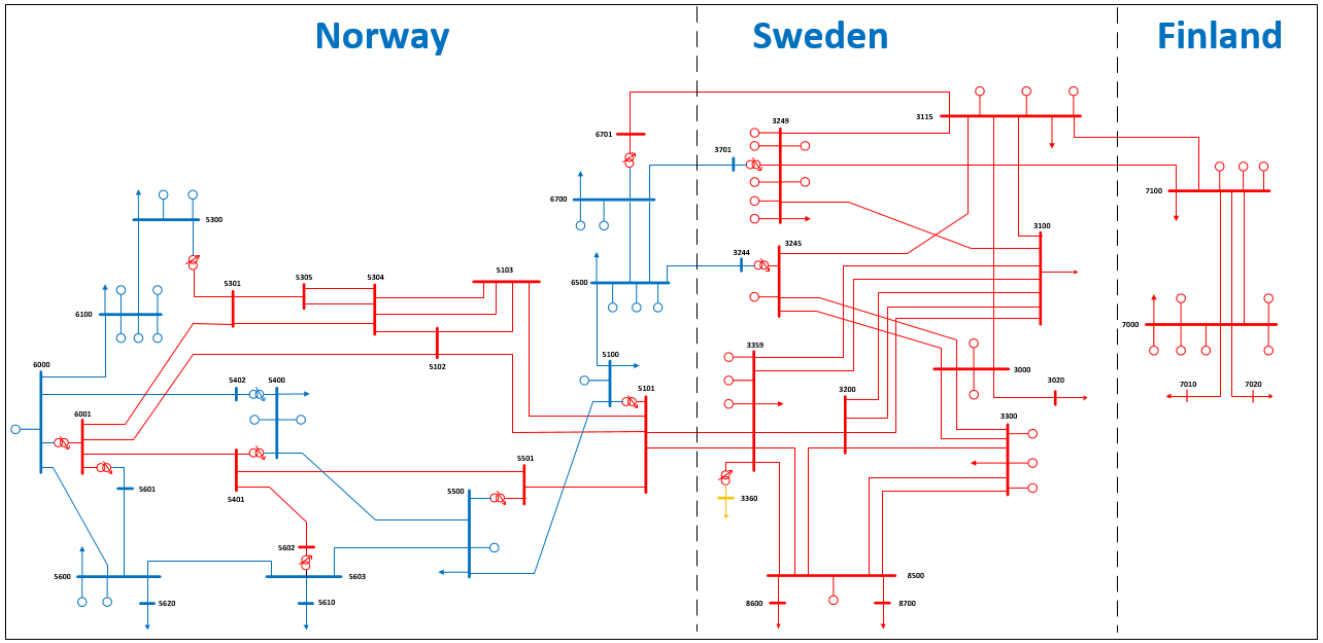
Demo 3

Real-time simulator

ePHASORSIM

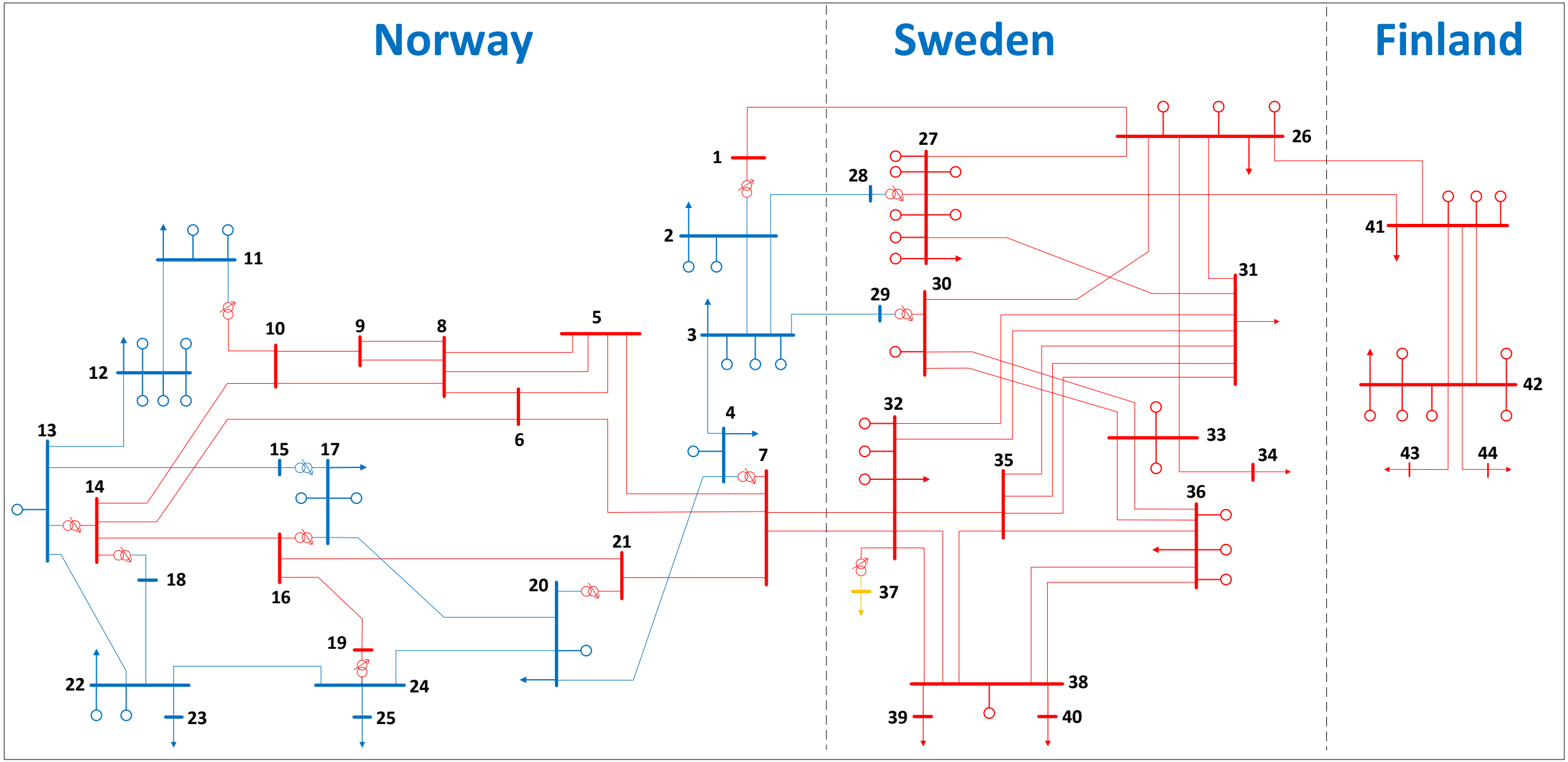


Control panel

PMU stream

GPS

Real-time applications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