Modelling and Control of Large Scale Electrolyzer (Power-to-Gas) in RTDS

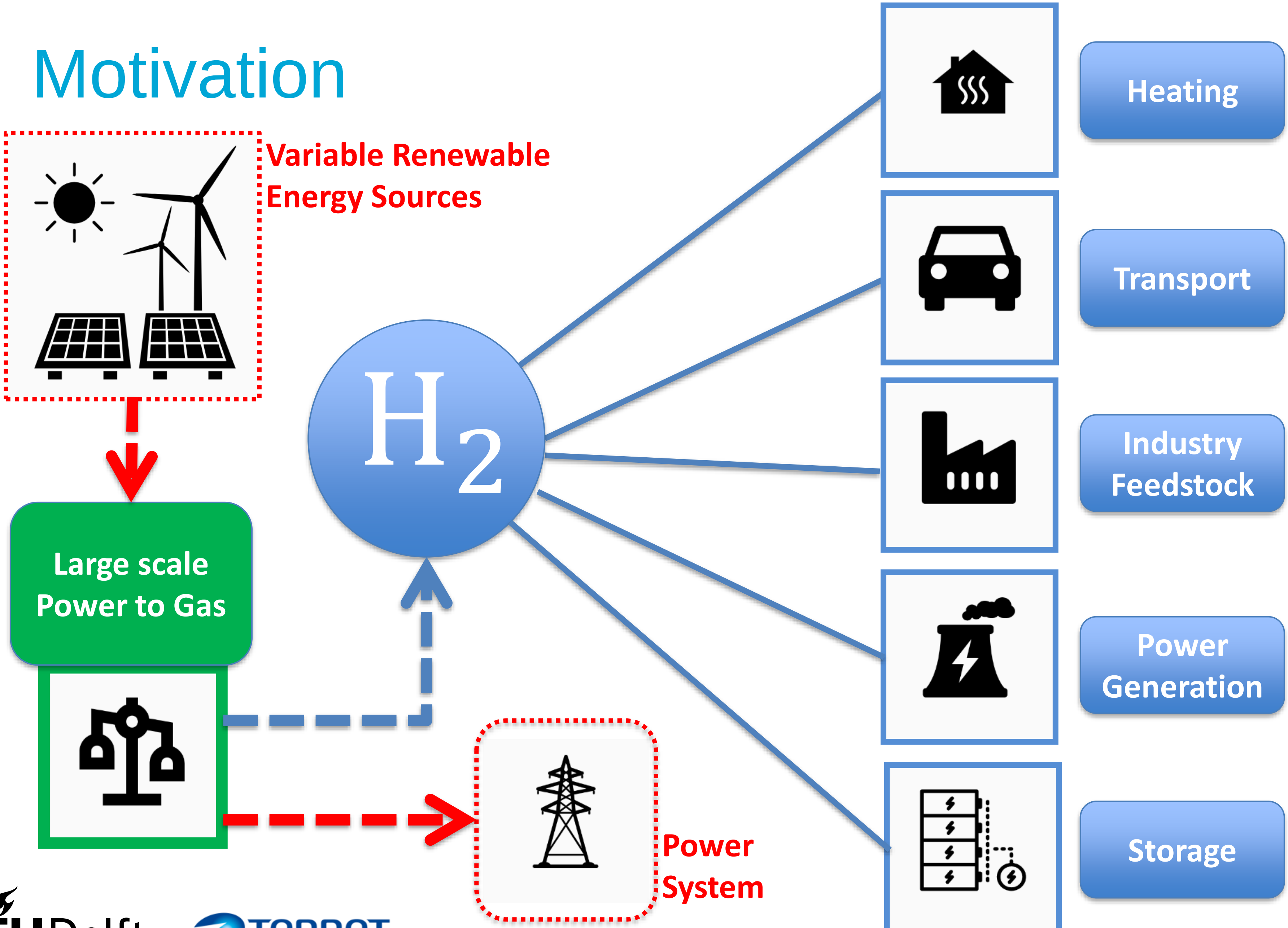
RTDS UGM 2018

Patrick Ayivor

TenneT

TU Delft

Motivation



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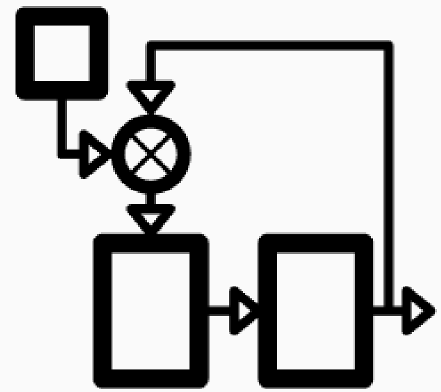
Objective

Large scale Power to Gas has potential

Potential impact not fully understood



Models don’t exist [2]

Develop a generic scalable RSCAD model + Control scheme

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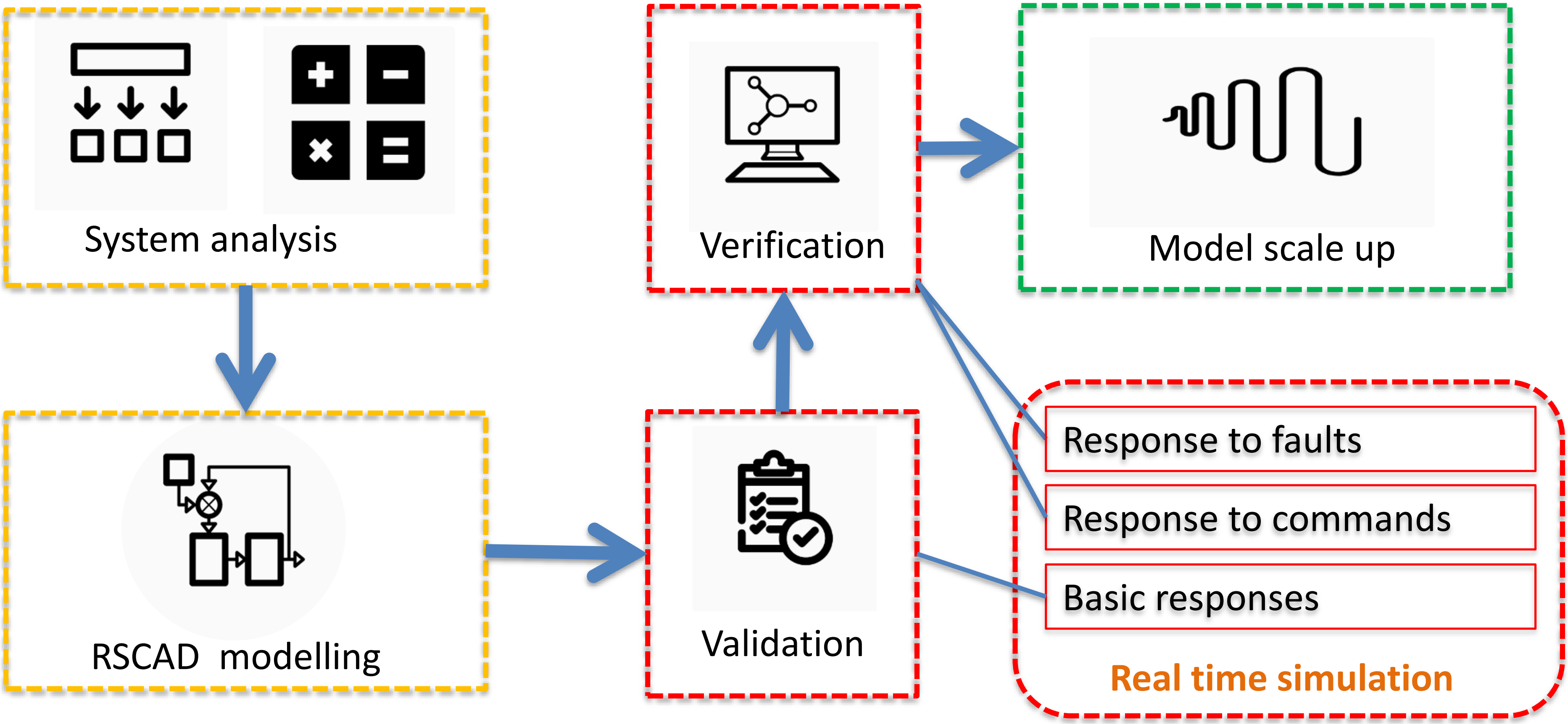
Process



Mathematical modelling and real time simulation using RTDS

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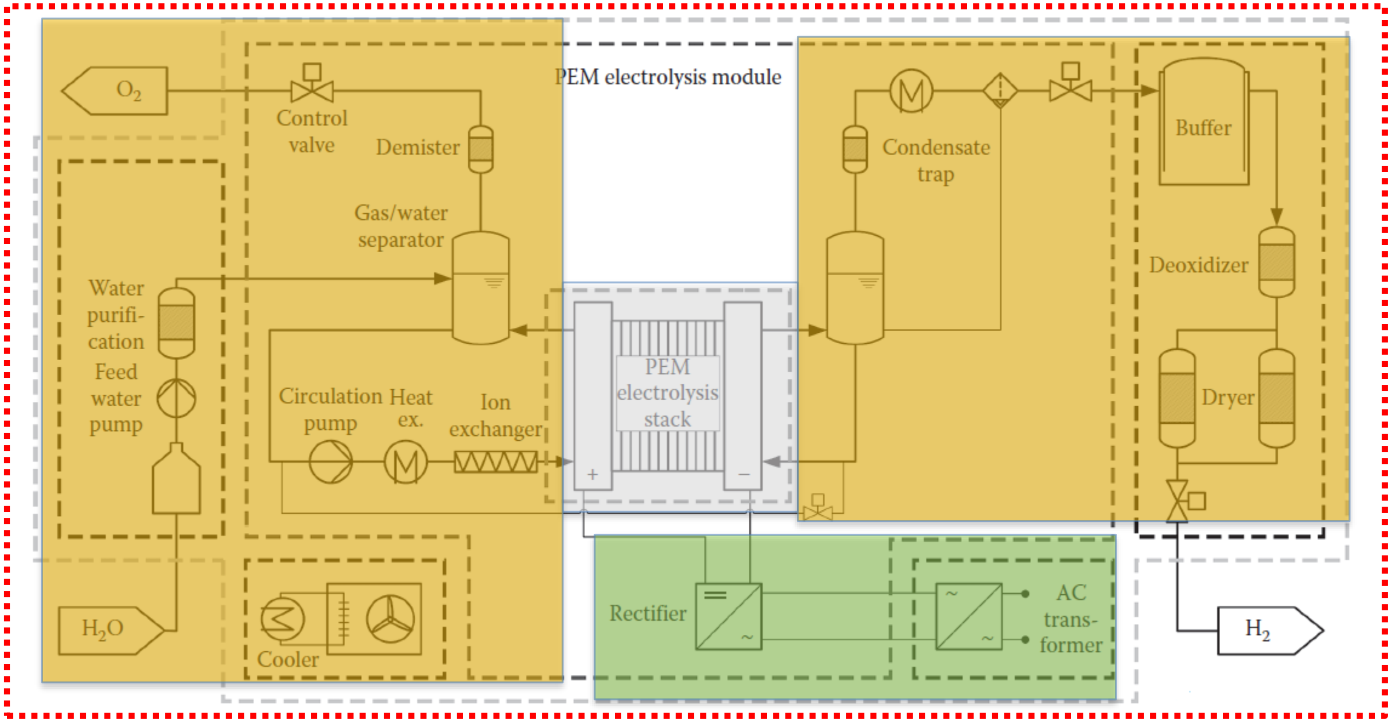
Key Subsystems and Functions

Polymer Electrolyte Membrane (PEM) stack

Balance of plant (BoP)

Power conversion system (PCS)

Control System



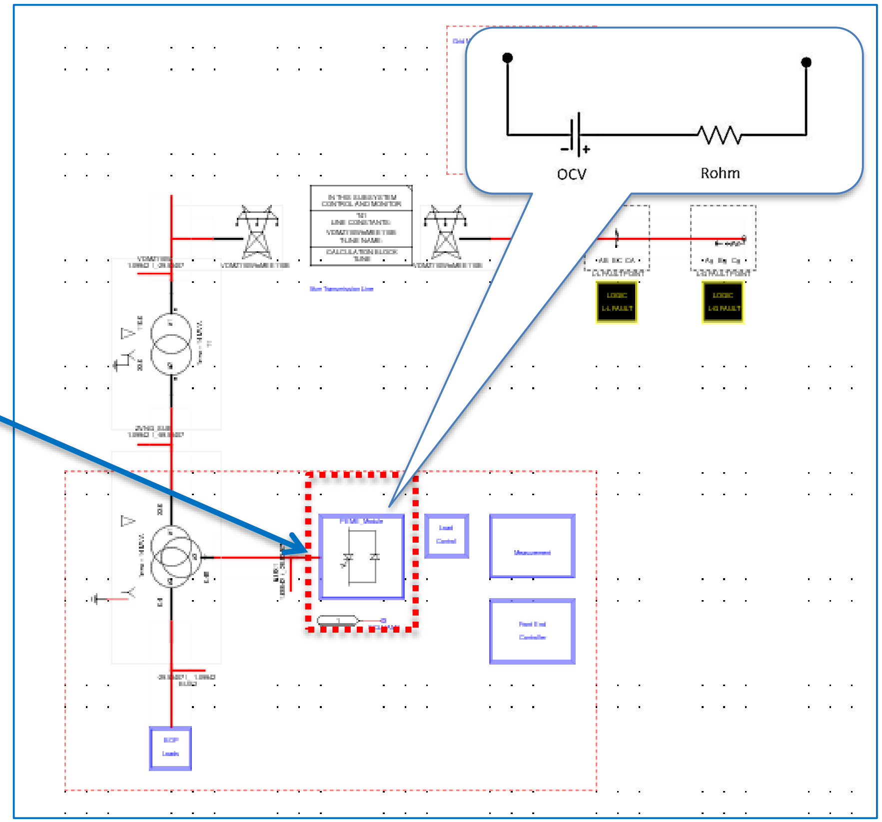
3 main subsystems + Control System

RSCAD Modelling - PEM Stack

$$H_2O \rightarrow \frac{1}{2}O_2(g) + 2H^+ + 2e^-$$

$$2H^+ + 2e^- \rightarrow H_2$$

Oxygen and Hydrogen Evolution Reactions



Hydrogen gas output is proportional to current fed to the stack

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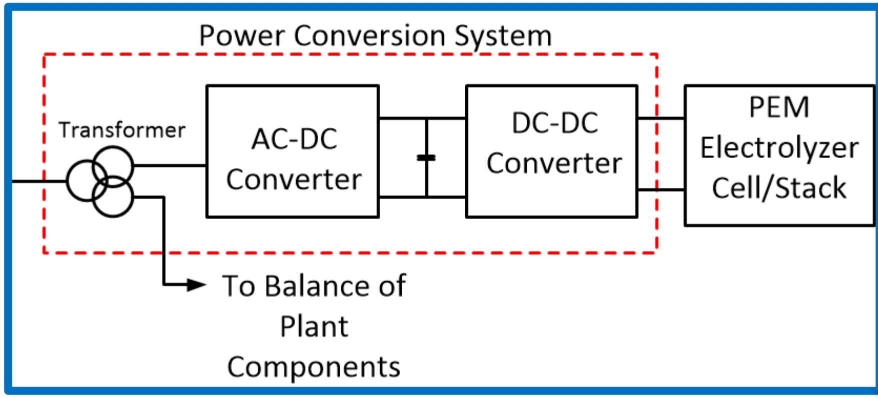
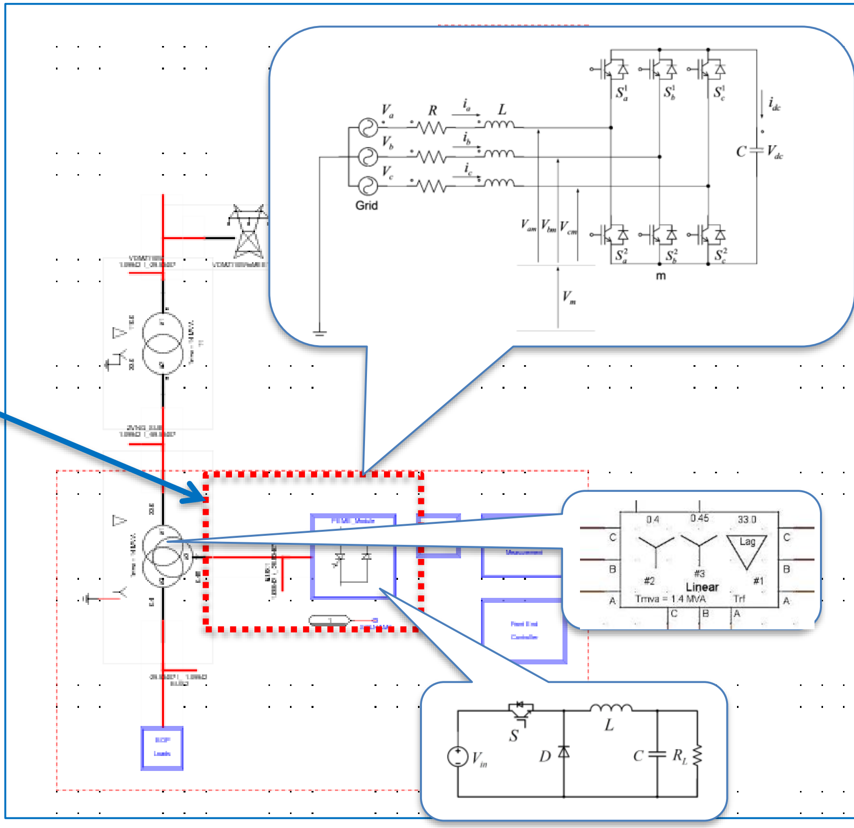
RSCAD Modelling - Power Conversion





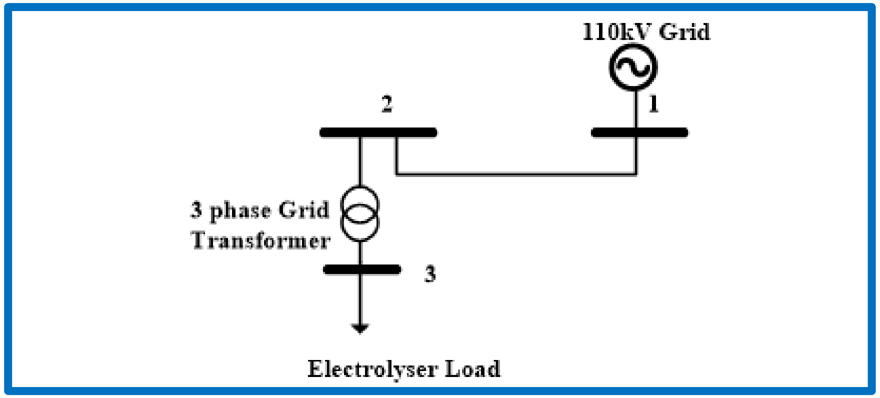
AC to DC conversion

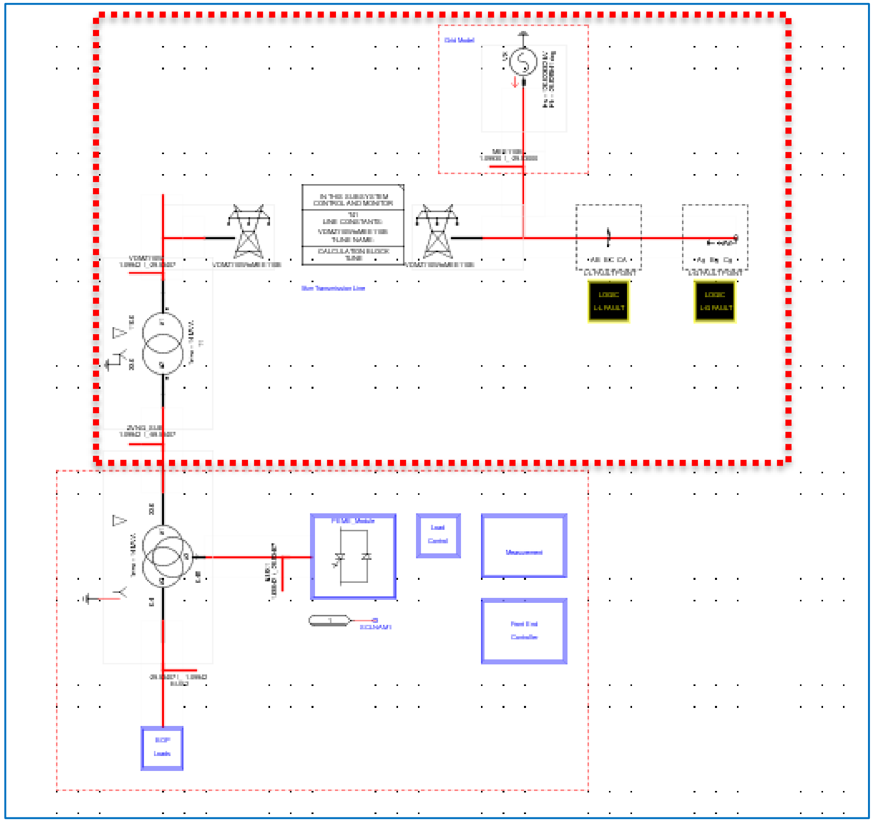
DC to DC conversion

AC Grid Voltage Reduction

Typical power supply for a large electrolyser comprises two converters

RSCAD Modelling - Test Network

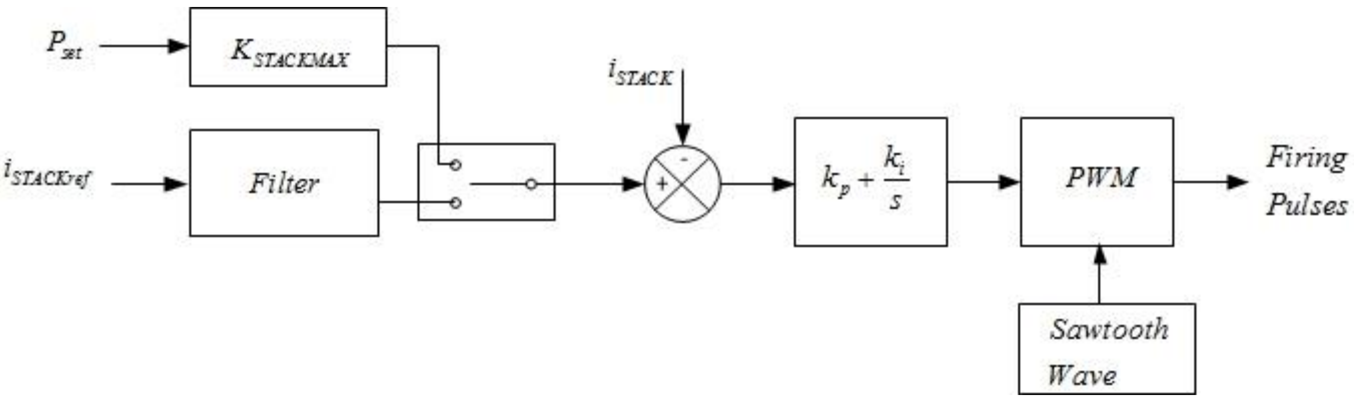




Transmission model based on a real interconnection in the power system.

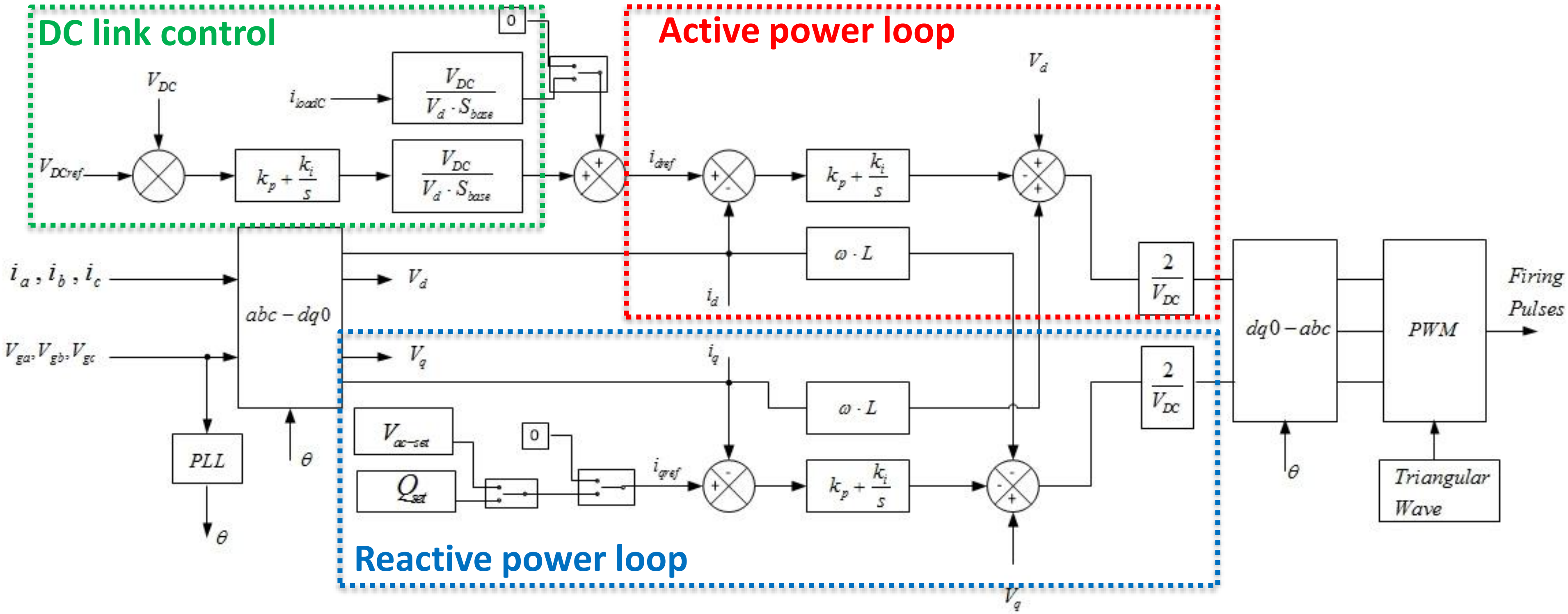
High voltage transmission system model

RSCAD Modelling - Converter Control



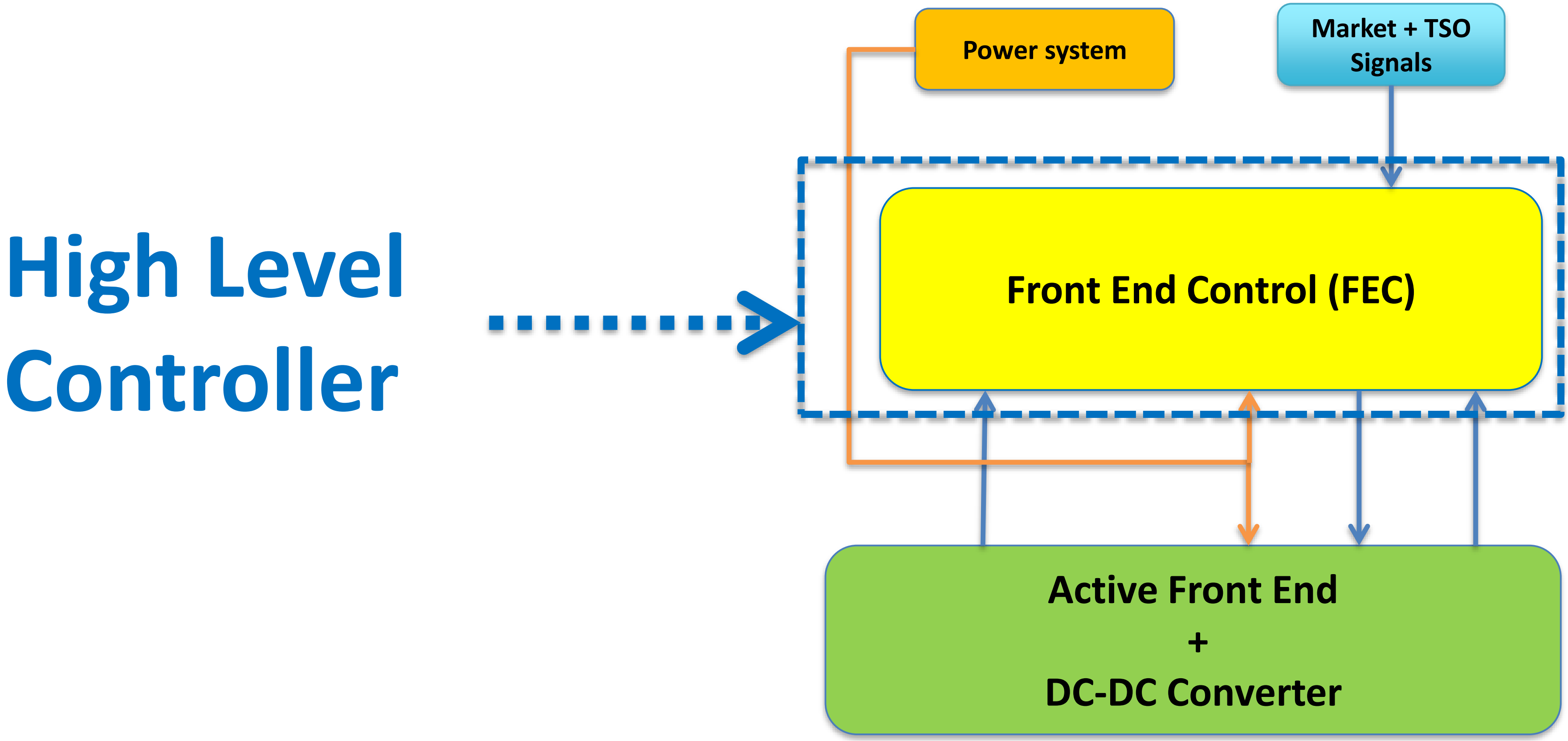
Stack current control is handled by DC-DC converter

RSCAD Modelling - Converter Control



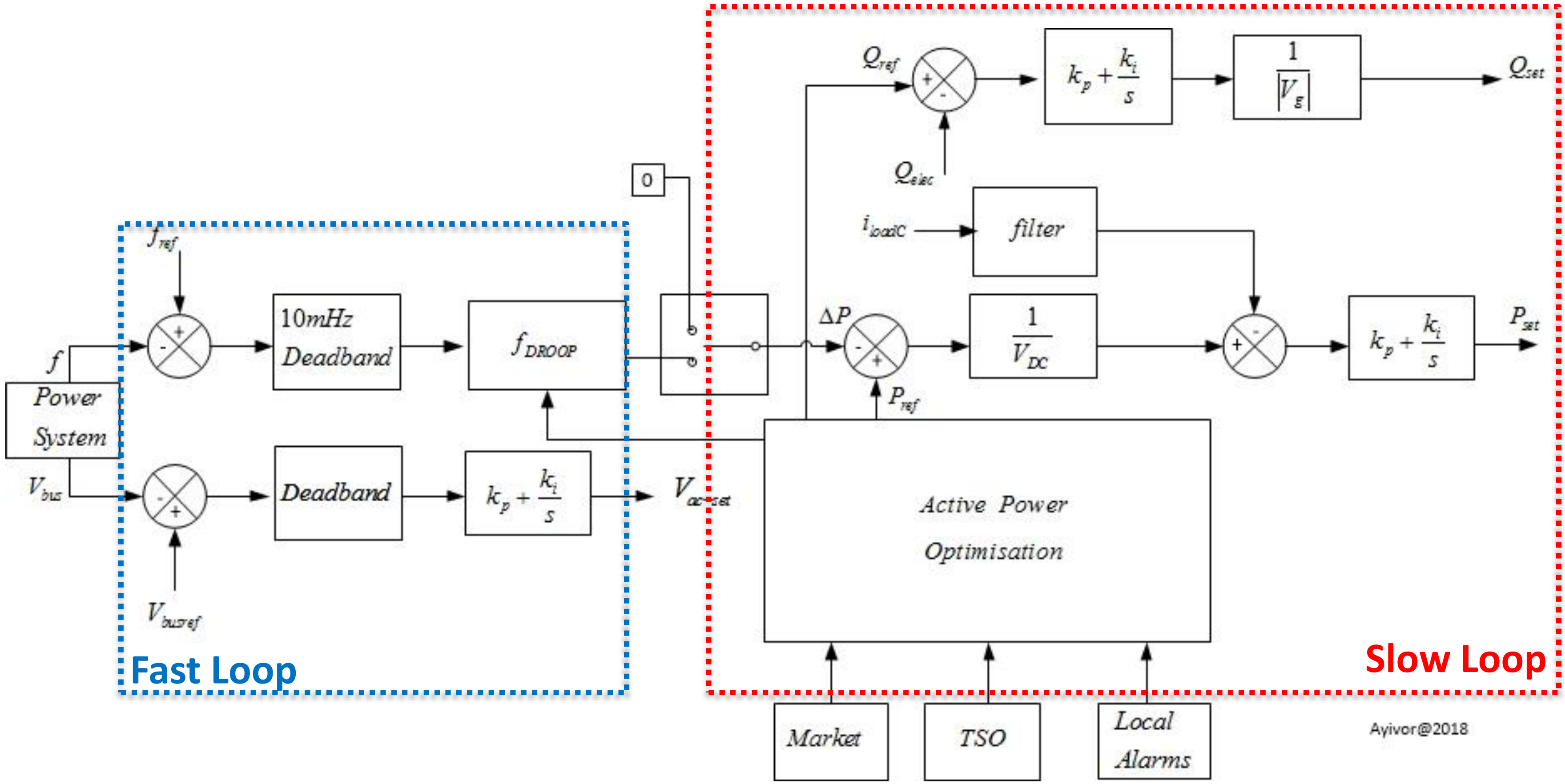
Grid current control is based on decoupled current control

Hierarchical Control Scheme



Hierarchical control system extends capabilities of large electrolysers to deliver ancillary services.

Control Scheme – High Level



High level control sets references for low level controls based on market and power system conditions.

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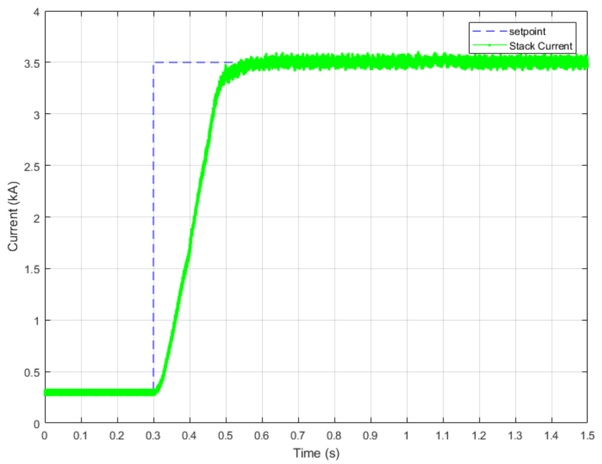
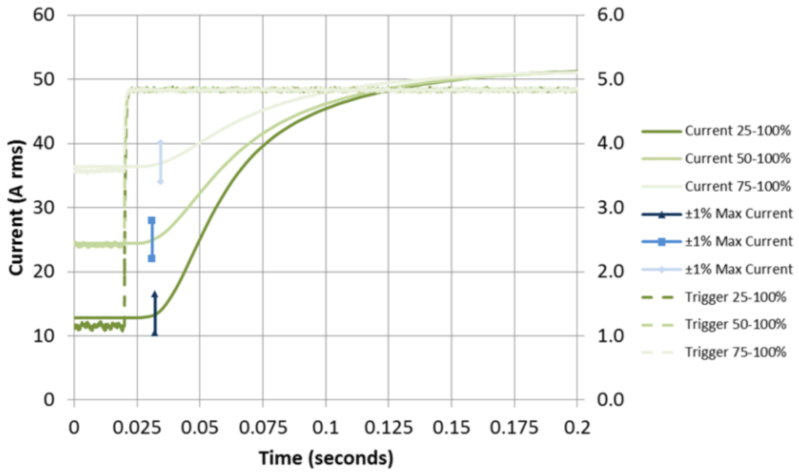
Basic Response – Ramp Up





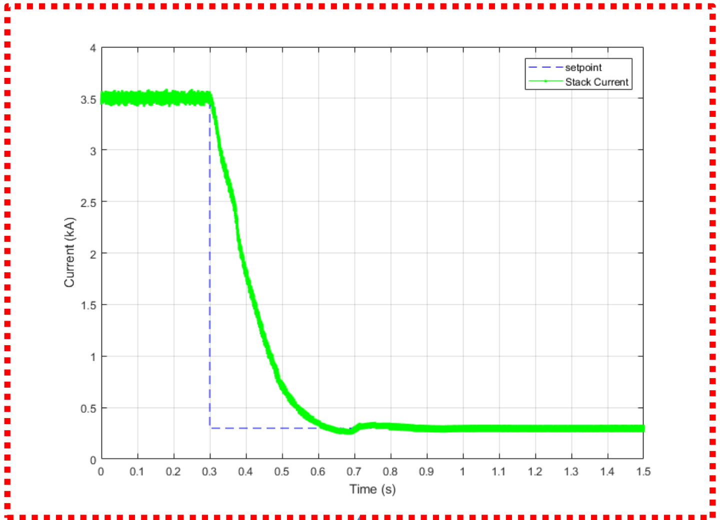
Model

Real Electrolyser

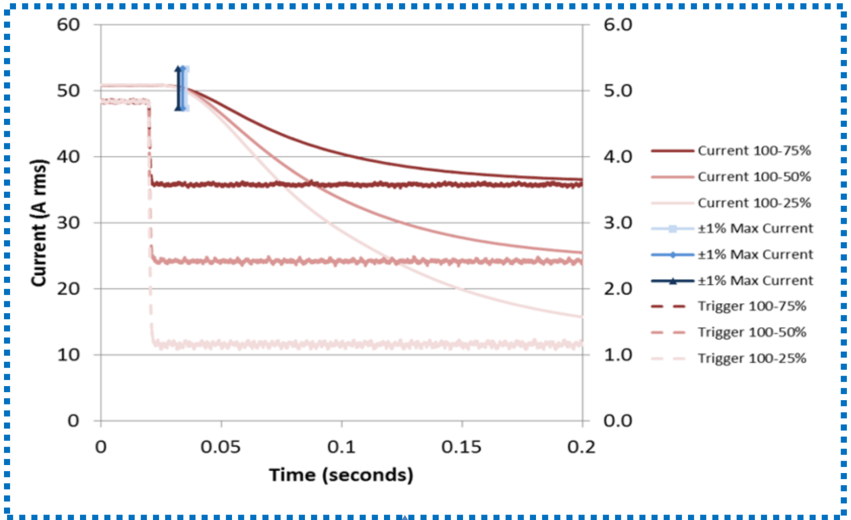
Step increase in stack current set point

Basic model can emulate electrolyser step response profile fairly accurately. Setpoint is achieved in less than 1 second.

Basic Response – Ramp Down



Model



Real Electrolyser

Step decrease in stack current set point

Basic model can emulate electrolyser step response profile fairly accurately. Setpoint is achieved in less than 1 second.

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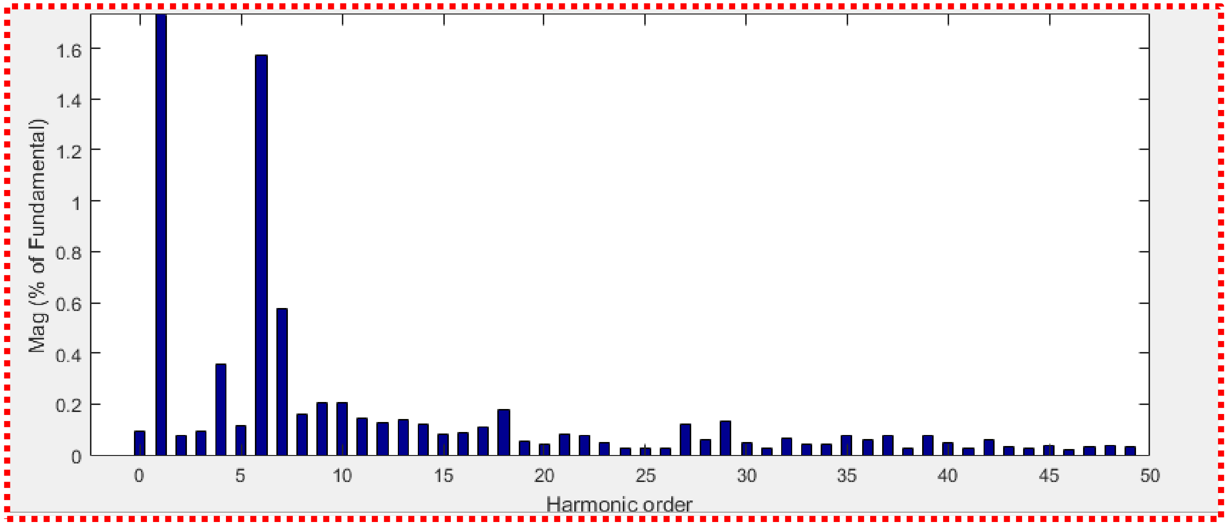
Total Harmonic Distortion



	Real electrolyser		1MW model		IEEE 519-2014
THD (Current)	1%	↔	2.38%	↔	5% - 20%*
THD (Voltage)	2.2%	↔	1.83%	↔	5%

THD of the model is comparable with that of real 1 MW system. THD measurement is at 33kV bus (Point of common connection)

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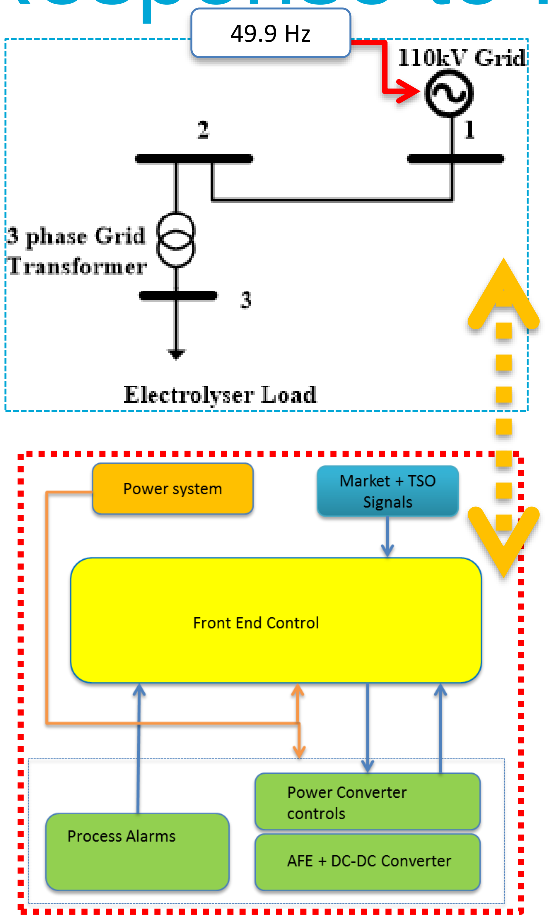
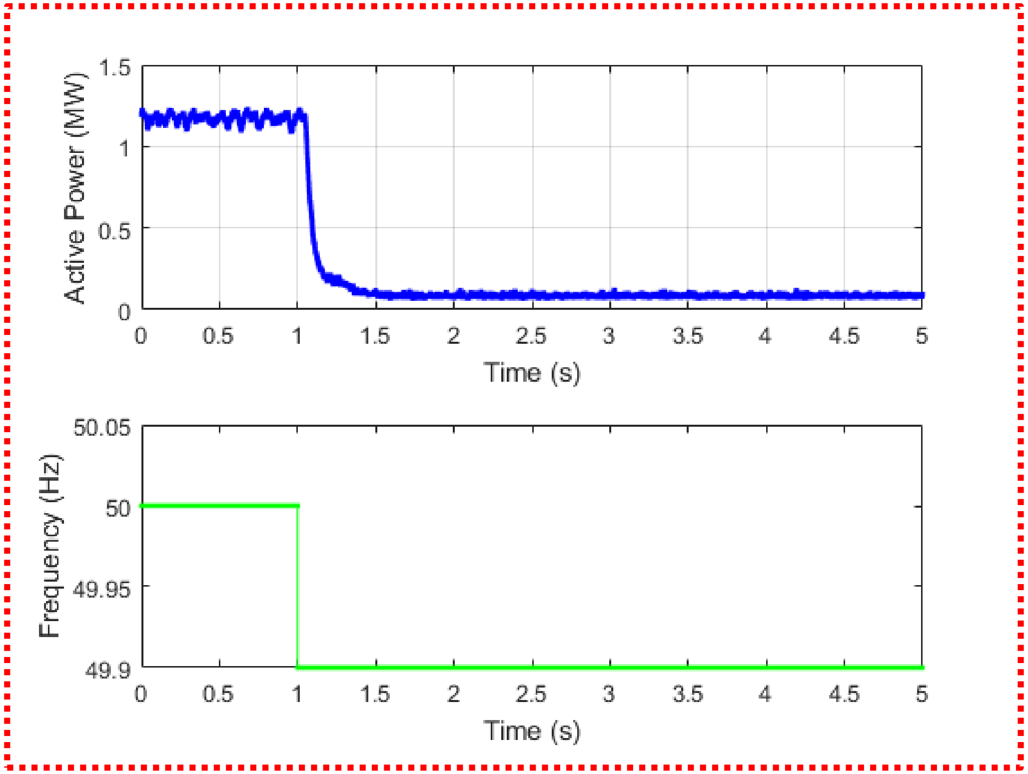
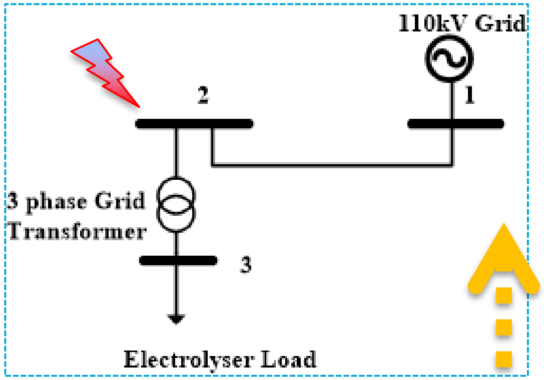
Response to Frequency Disturbance

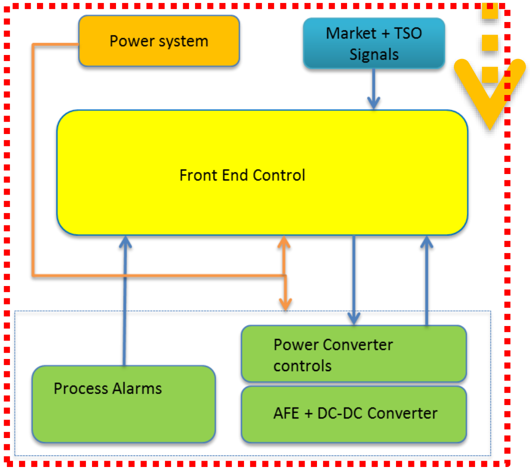


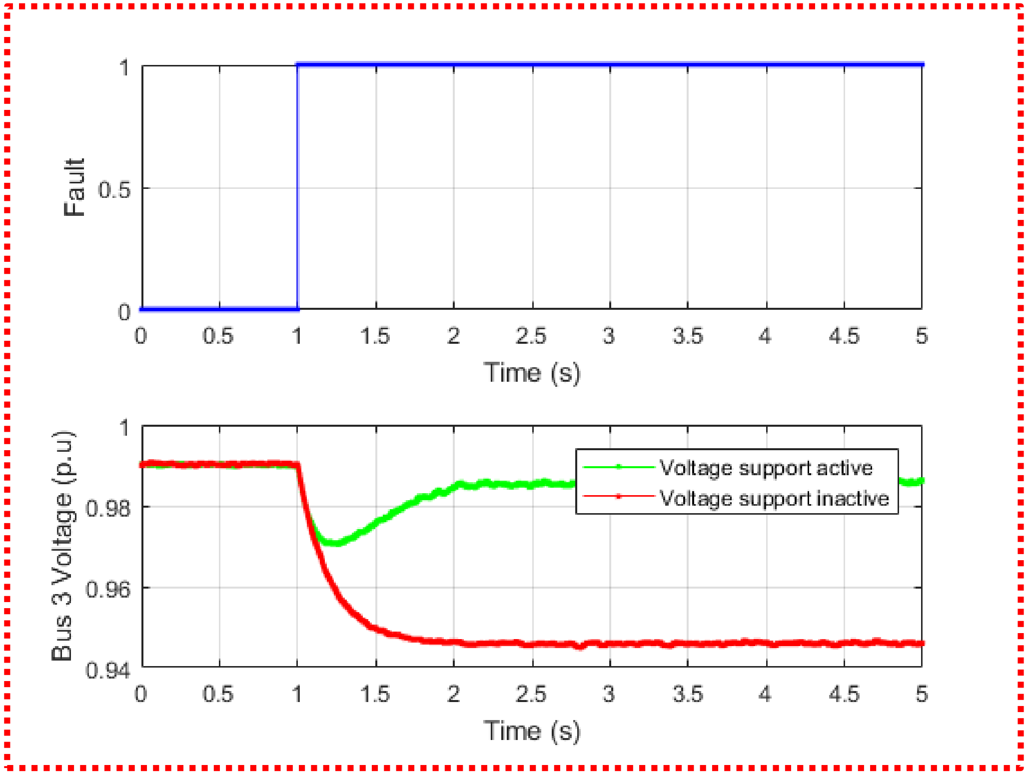


Extended model with FEC enables frequency support. Response to disturbance is triggered when system frequency deviates from 50Hz.

Response to Voltage Disturbance

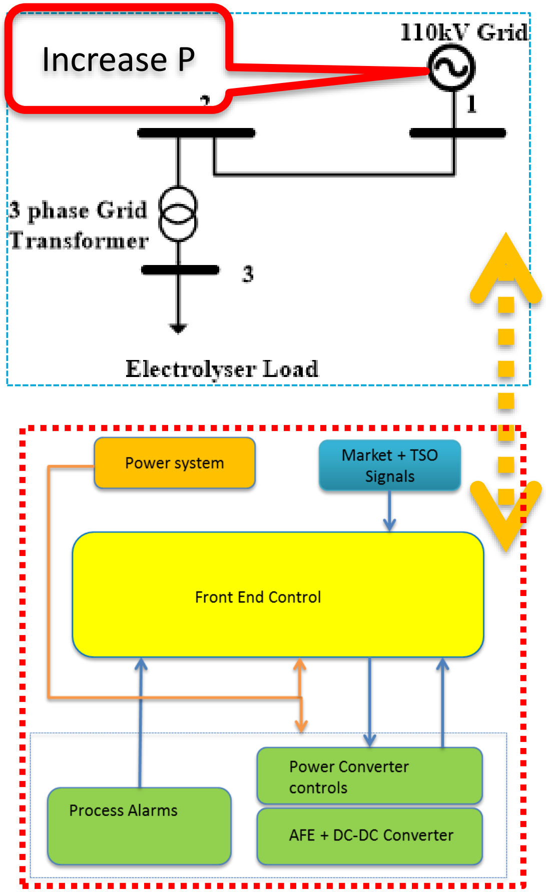


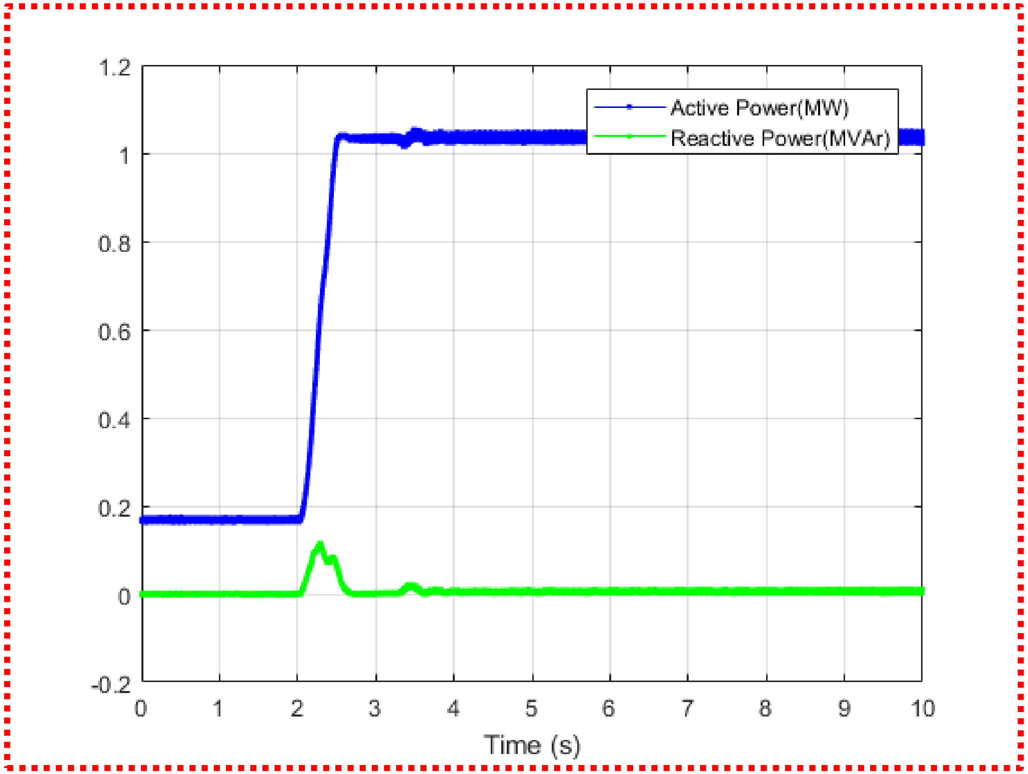




Extended model with FEC enables bus voltage support. Response to disturbance is triggered when voltage deviates from reference.

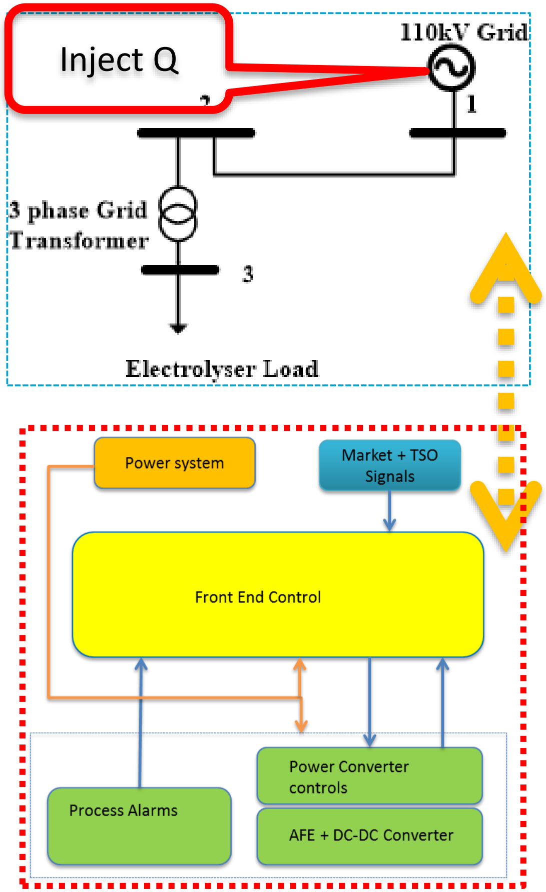
Response to TSO Command

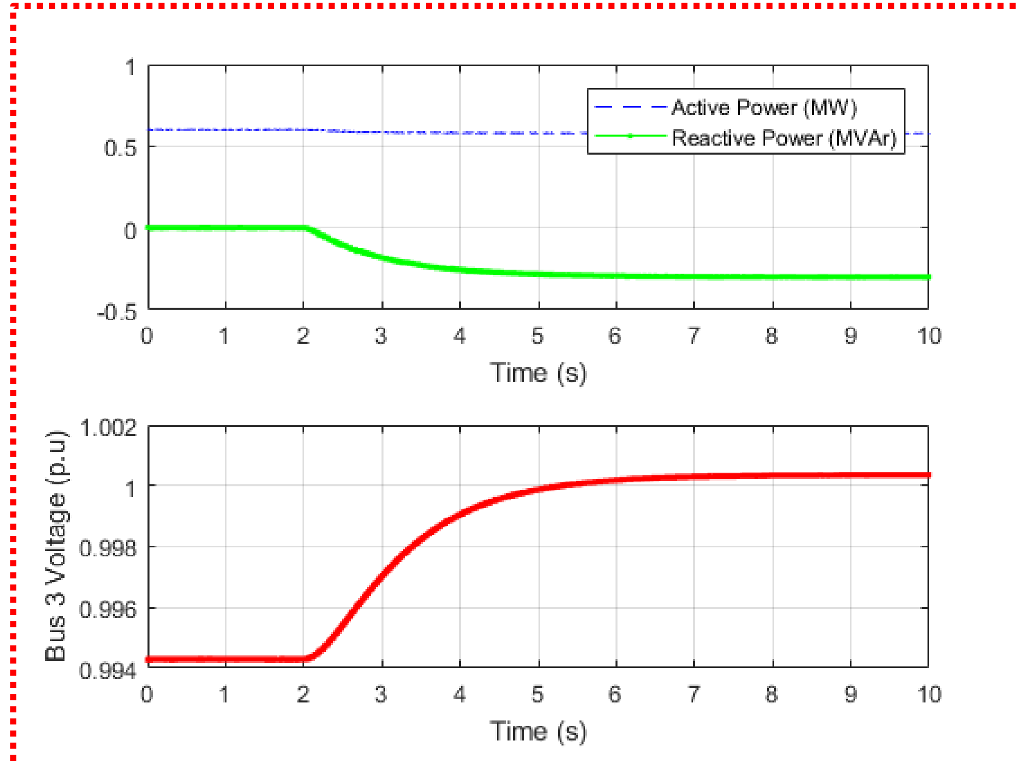




Extended model with FEC receives external commands to increase active power. This is independent of reactive power control.

Response to TSO Command





Extended model with FEC receives external commands to inject reactive power.

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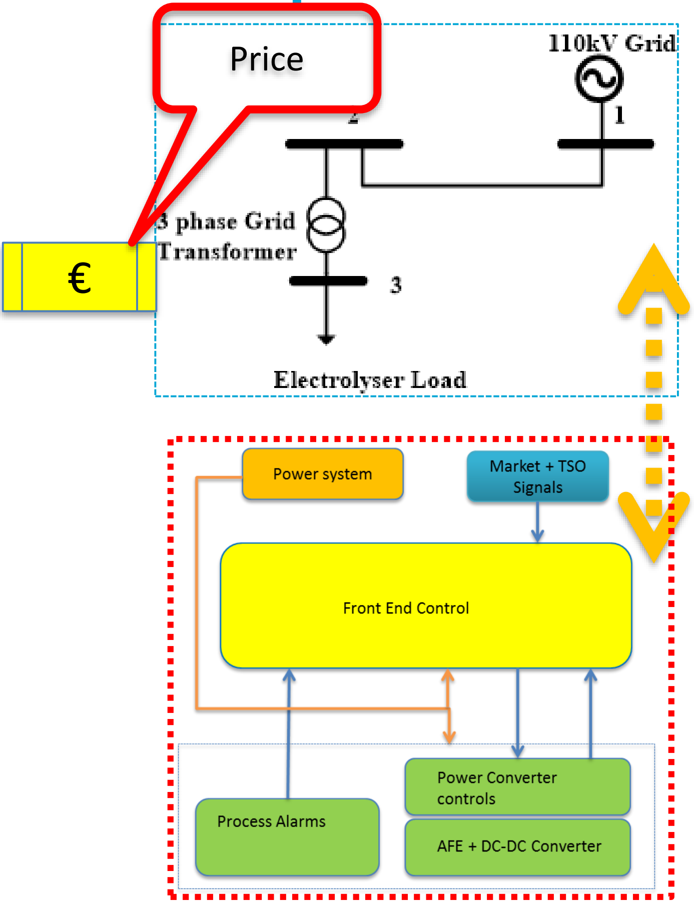
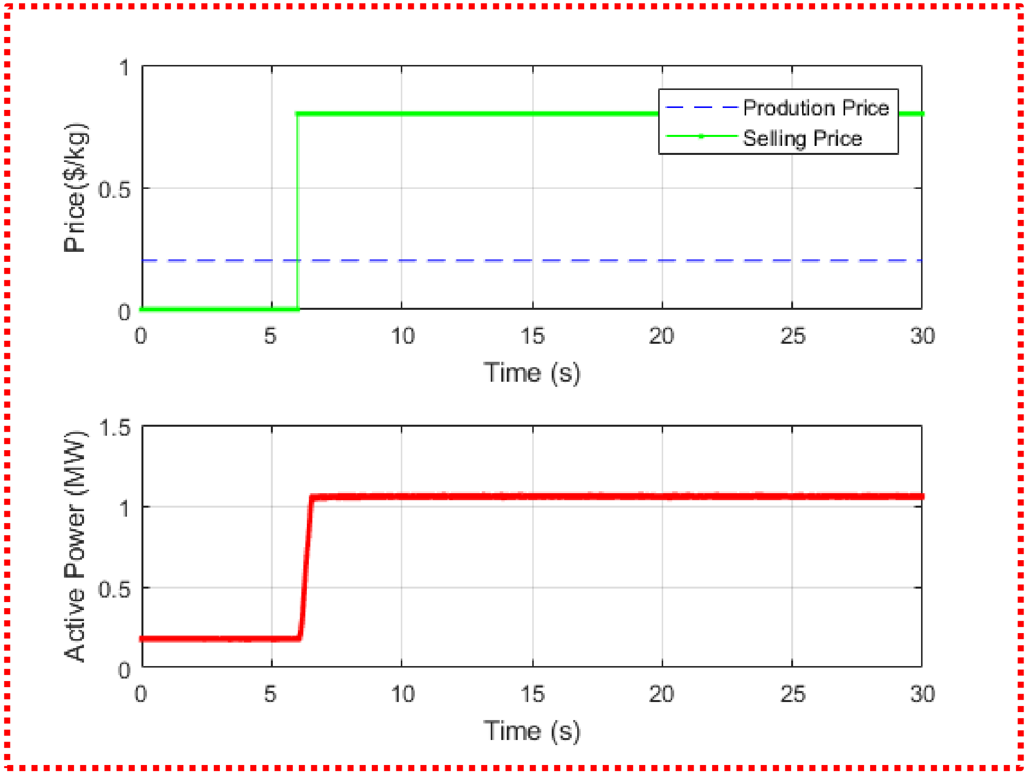
Response to Market/Price Signal





FEC enables automatic response to price signals. Active power adjustments are made in response to price in real time.

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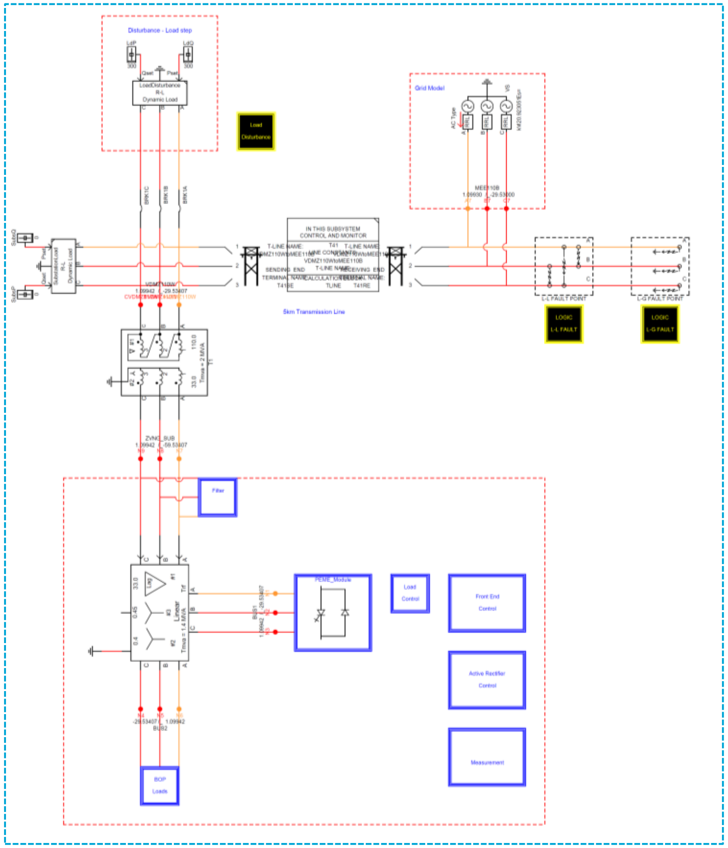
Model Capabilities and Limitations



- Frequency Support
- Voltage Support
- Congestion Management

✓ Ease of integration

✓ Simplicity

✓ Maintainability

✓ Reusability

❖ Harmonic distortion for scaled versions

Model can be **easily scaled** and deployed in any grid model.
Harmonic distortion needs to be improved.

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Thank you!

More information available at :

https://repository.tudelft.nl/

OR

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