LOWEMISSION

CleanOFF Hub

SINTEF NTNU

An electromagnetic transient model of a wind-powered grid-forming energy hub for an offshore platform cluster

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January 2025

Acknowledgments
This research was funded by the Research Council of Norway, under the program PETROMAKS2, grant number 326725, project "Clean Offshore Heat and Power Hub – CleanOFF Hub".

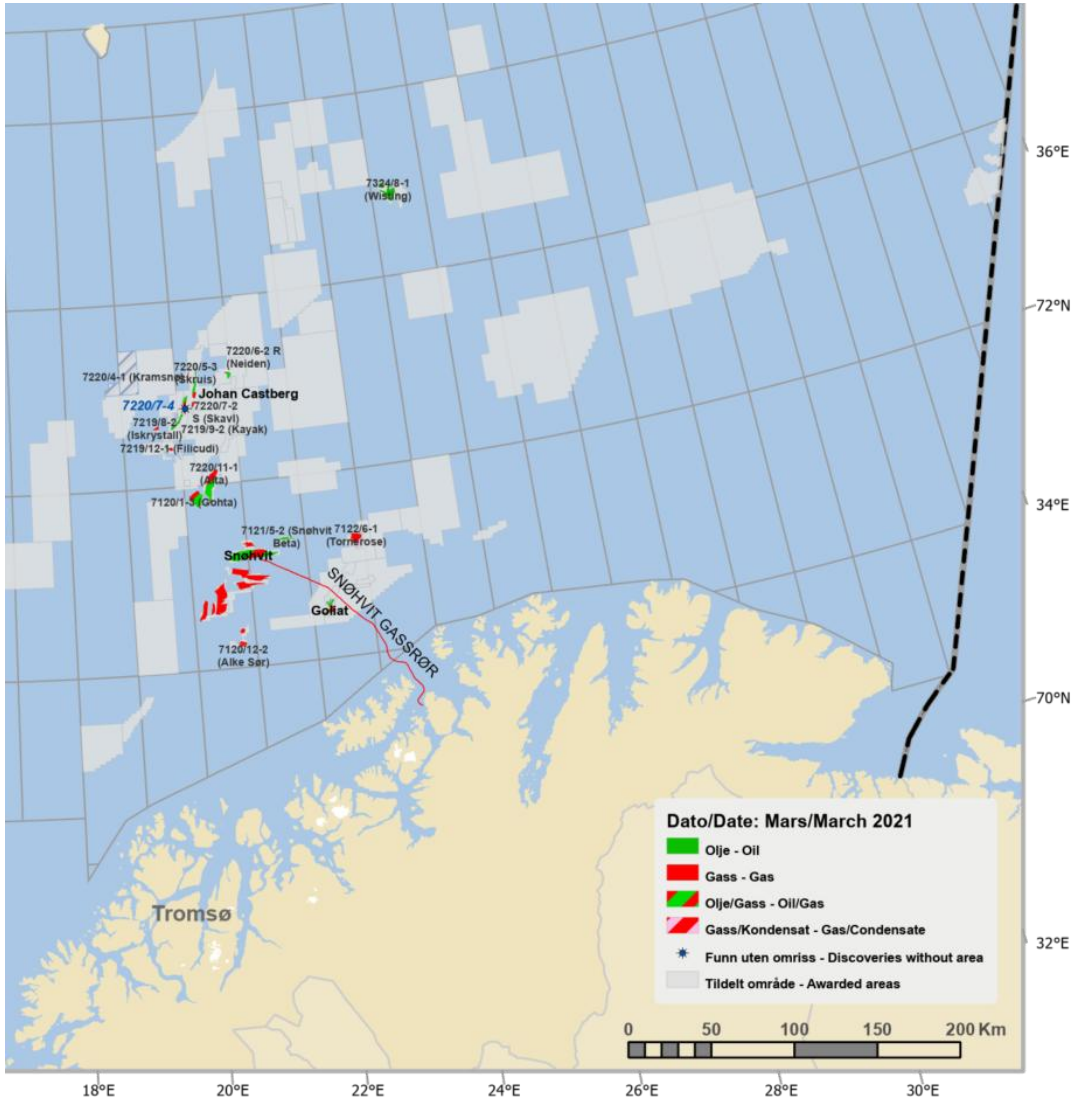
PROJECT

CleanOFF Hub

The project addresses Norway's ambition to decarbonise the offshore petroleum sector while retaining its international competitiveness.

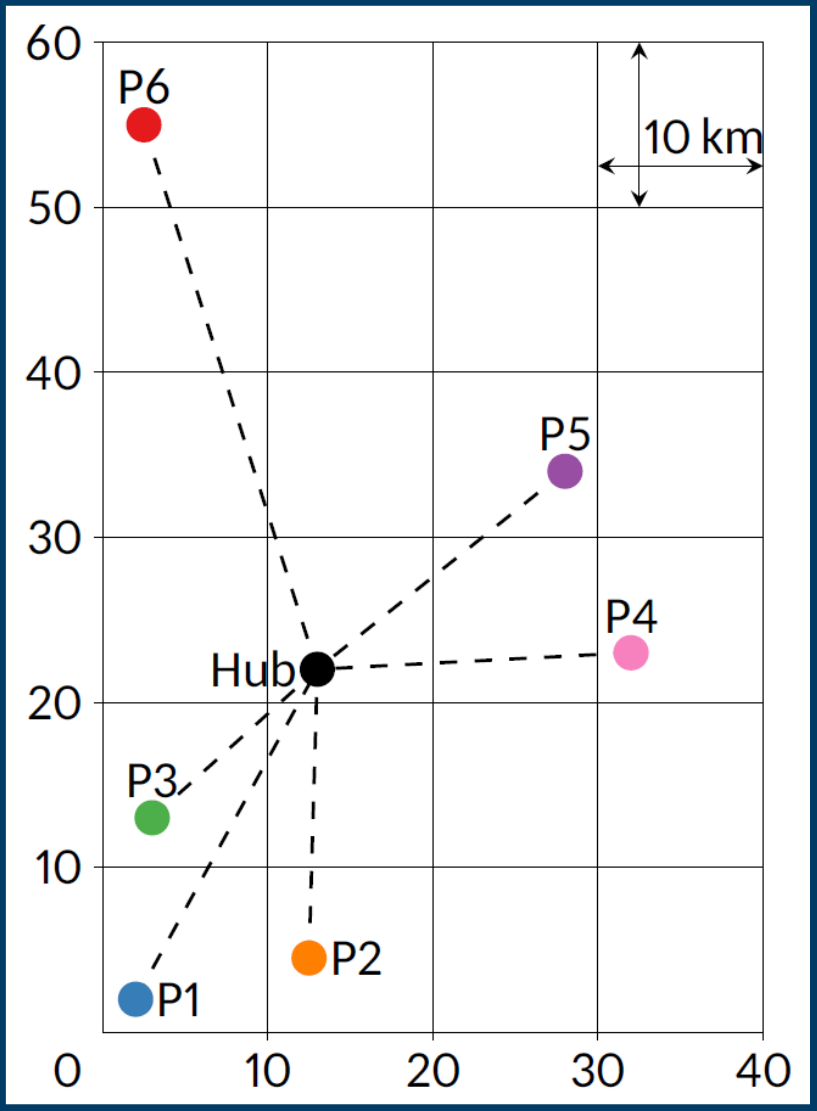
CleanOFF Hub Concept
Several facilities ≥ 240 km from shore

- Electric power:
  - 50 to 150 MW/facility at plateau
- Heat:
  - 30 to 70 MW/ facility at plateau

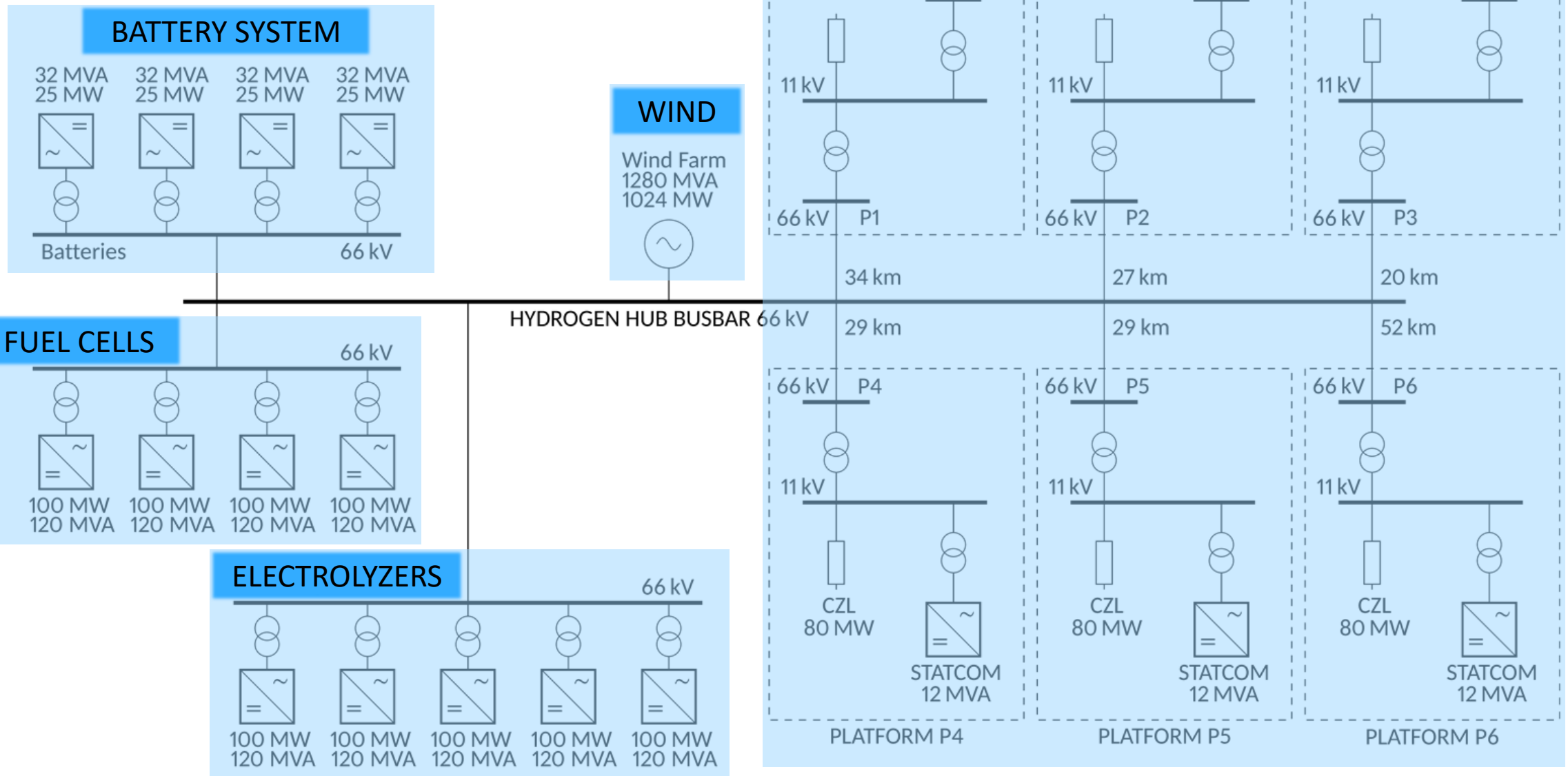


An electromagnetic transient model of a grid-forming energy hub supplied by wind for an offshore platform cluster

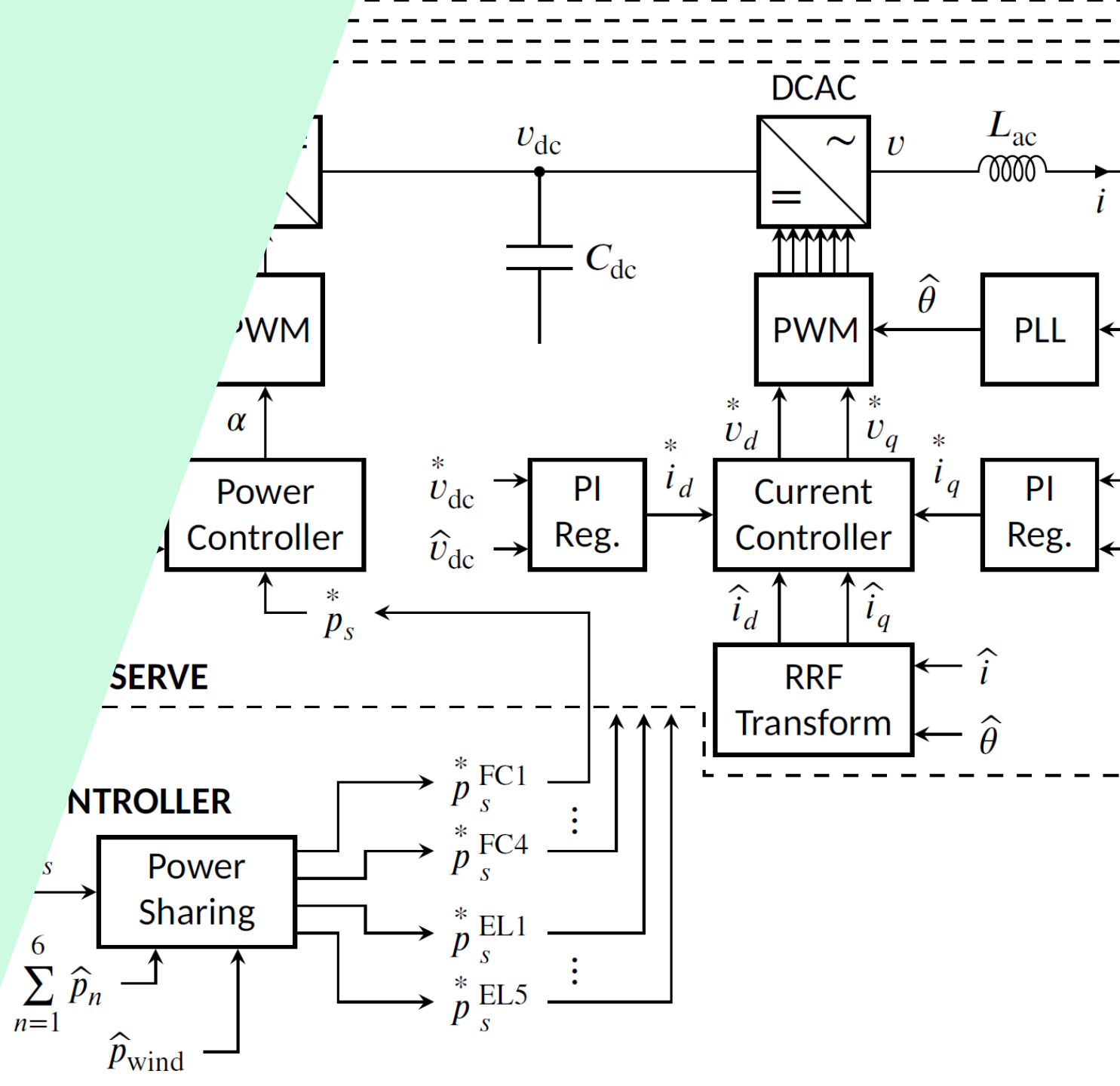
Platform	Load
P1	115 MW
P2	115 MW
P3	80 MW
P4	80 MW
P5	80 MW
P6	80 MW
Total load	550 MW




PowerFactory
SILENT
DIG


BATTERY SYSTEM
32 MVA
25 MW
32 MVA
25 MW
32 MVA
25 MW
32 MVA
25 MW
Batteries
66 kV
WIND
Wind Farm
1280 MVA
1024 MW
HYDROGEN HUB BUSBAR 66 kV
FUEL CELLS
66 kV
100 MW
120 MVA
100 MW
120 MVA
100 MW
120 MVA
100 MW
120 MVA
ELECTROLYZERS
66 kV
100 MW
120 MVA
100 MW
120 MVA
100 MW
120 MVA
100 MW
120 MVA
100 MW
120 MVA
PLATFORMS
PLATFORM P1
PLATFORM P2
PLATFORM P3
STATCOM
12 MVA
LEOGO
115 MW
CZL
115 MW
CZL
80 MW
11 kV
66 kV
P1
P2
P3
34 km
27 km
20 km
29 km
29 km
52 km
P4
P5
P6
CZL
80 MW
PLATFORM P4
PLATFORM P5
PLATFORM P6

Frequency Control



Frequency Control

Primary Control

Batteries
4 x 25MW
Grid Forming

Proportional response to AC frequency variations in the HUB

Secondary Control

HUB AC Frequency → **PI Controller**

Total Secondary Power

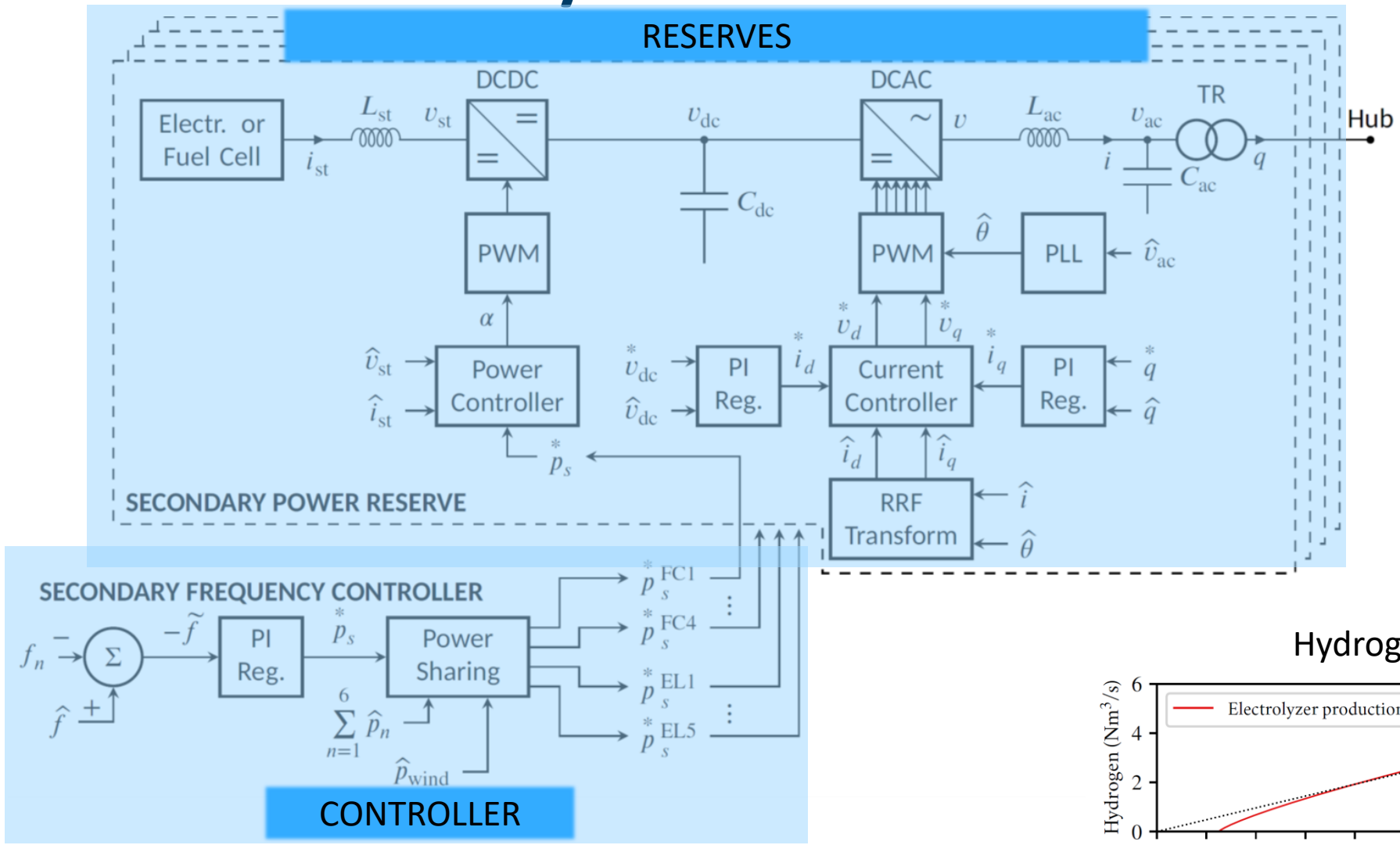
Power Sharing

Secondary Power Quotas

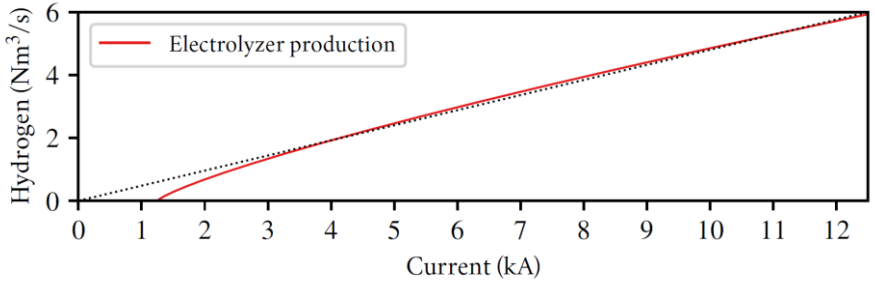
Fuel Cells
4 x 100 MW

Electrolysers
5 x 100 MW

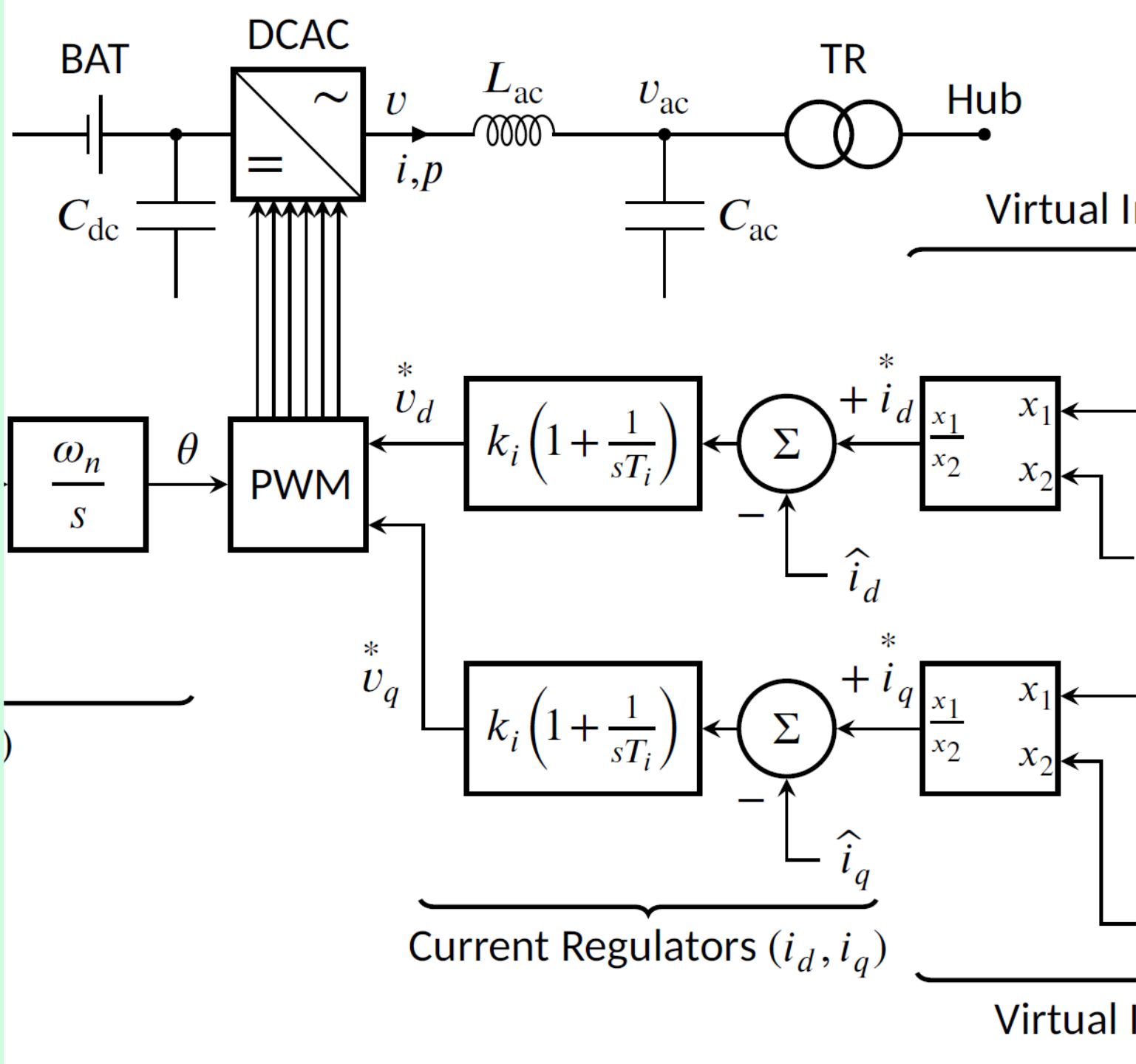
Secondary Frequency Controller / Reserves



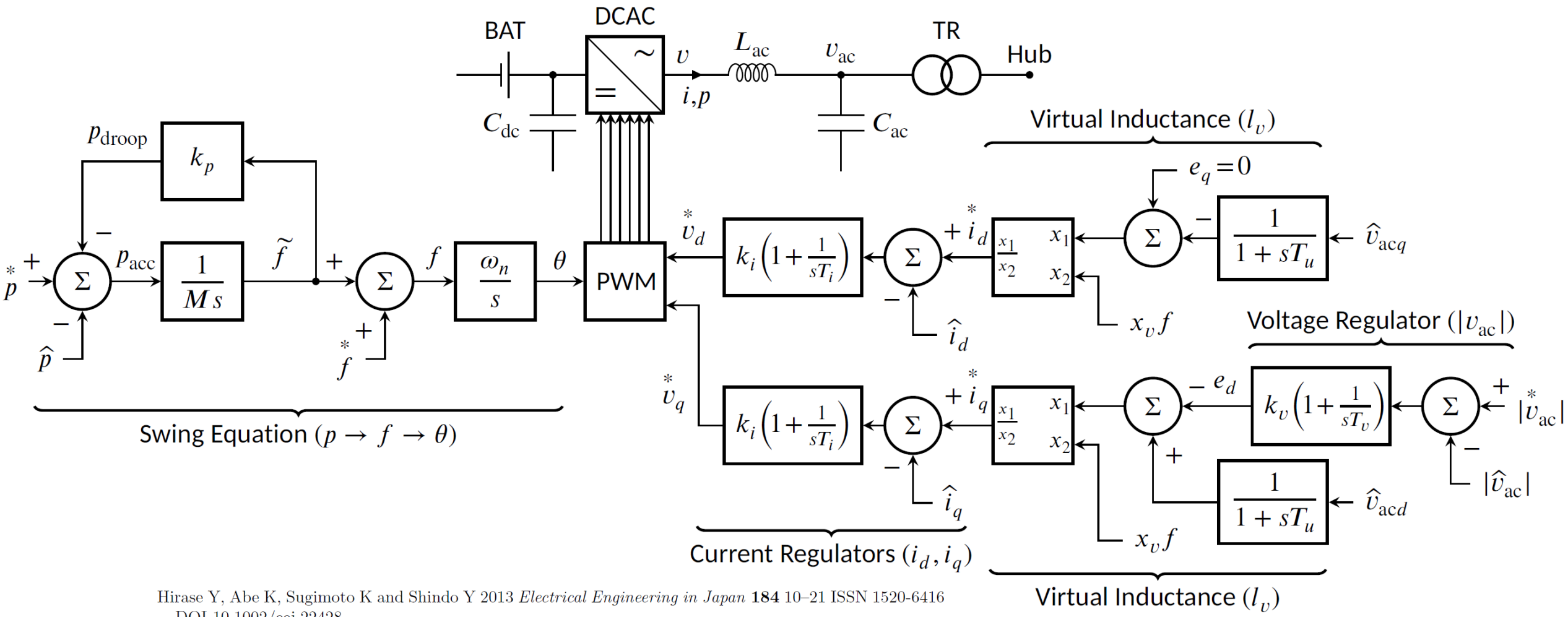
Hydrogen production



Primary Control
Virtual synchronous machines



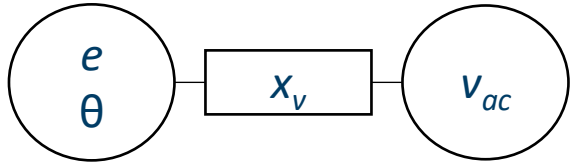
Quasi-stationary electric model (QSEM) Virtual Synchronous Machine (VSM)



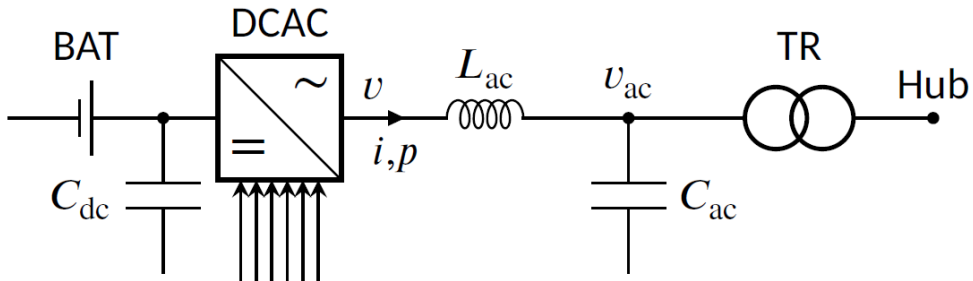
Hirase Y, Abe K, Sugimoto K and Shindo Y 2013 *Electrical Engineering in Japan* **184** 10–21 ISSN 1520-6416 DOI 10.1002/eej.22428

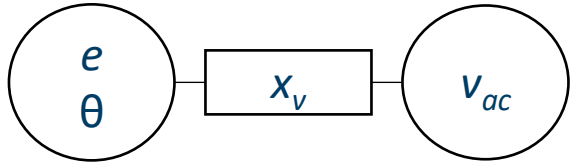
Mo O, D'Arco S and Suul J A 2017 *IEEE Transactions on Industrial Electronics* **64** 5952–5962 ISSN 1557-9948 DOI 10.1109/TIE.2016.2638810

Quasi-stationary electric model (QSEM) VSM Emulates a Voltage Behind an Impedance



Quasi-stationary electric model (QSEM) VSM Mechanical and Electrical Parts





Virtual Turbine and Governor
Rotating Mass
Power-to-Frequency Droop
Rotor angle (θ)

θ

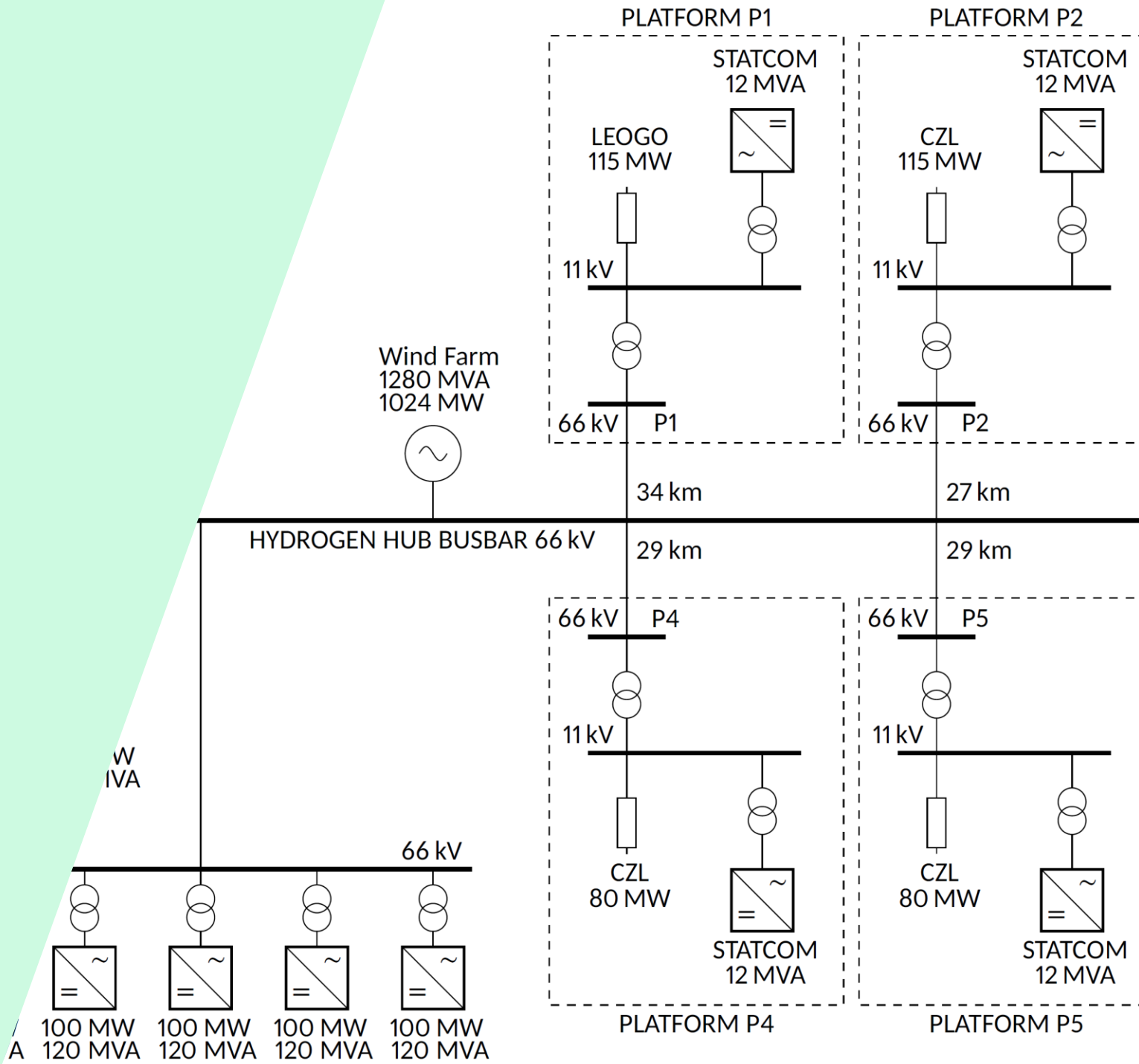
PWM

v_d^*

v_q^*

Virtual Generator and Voltage Regulator
Automatic Voltage Regulator
Internal Voltage
Virtual Impedance
Current Controllers
Converter Voltage (v_d *and* v_q)

Wind Farm


PLATFORM P1
PLATFORM P2
STATCOM
12 MVA
STATCOM
12 MVA
LEOGO
115 MW
CZL
115 MW
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1280 MVA
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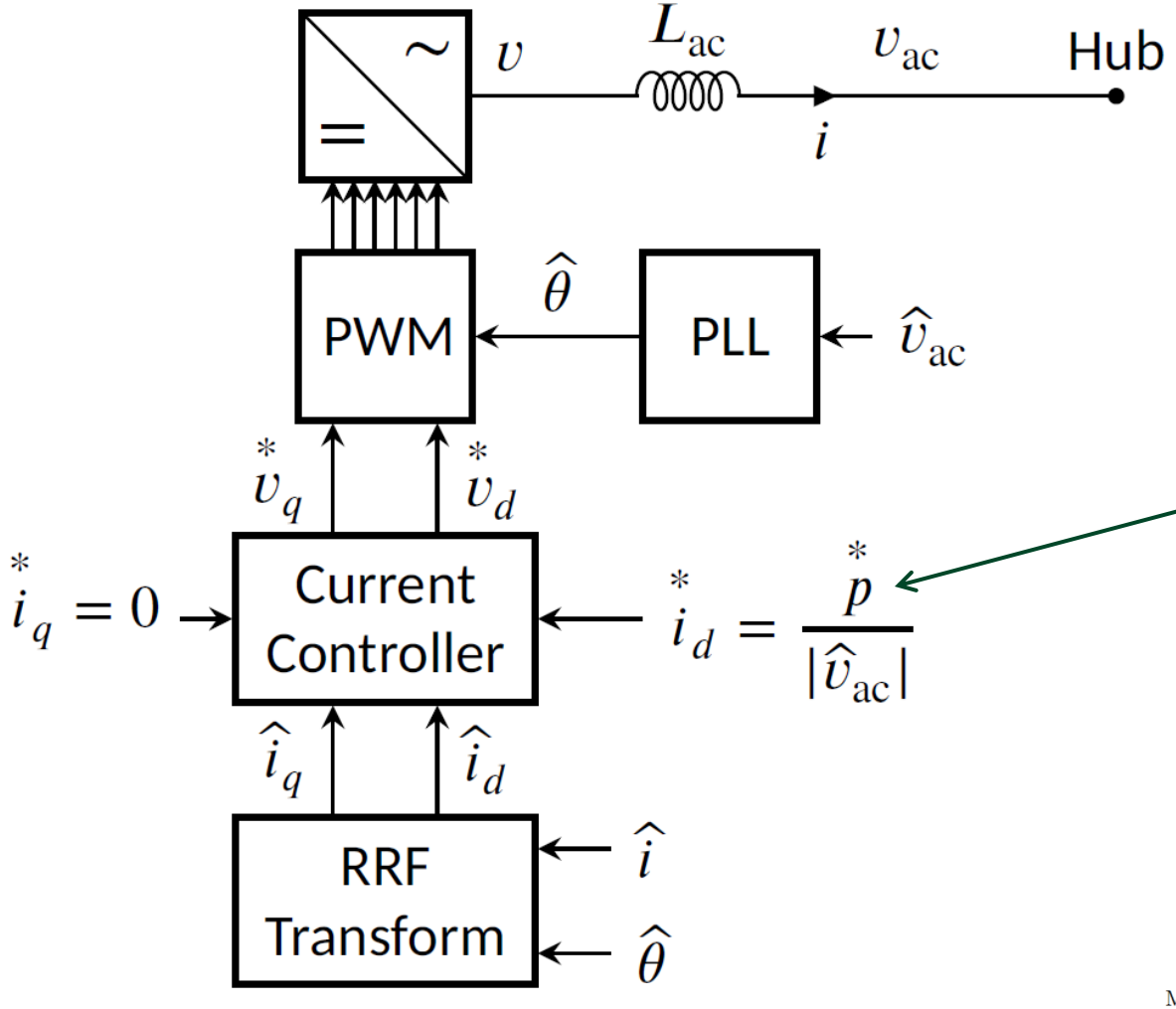
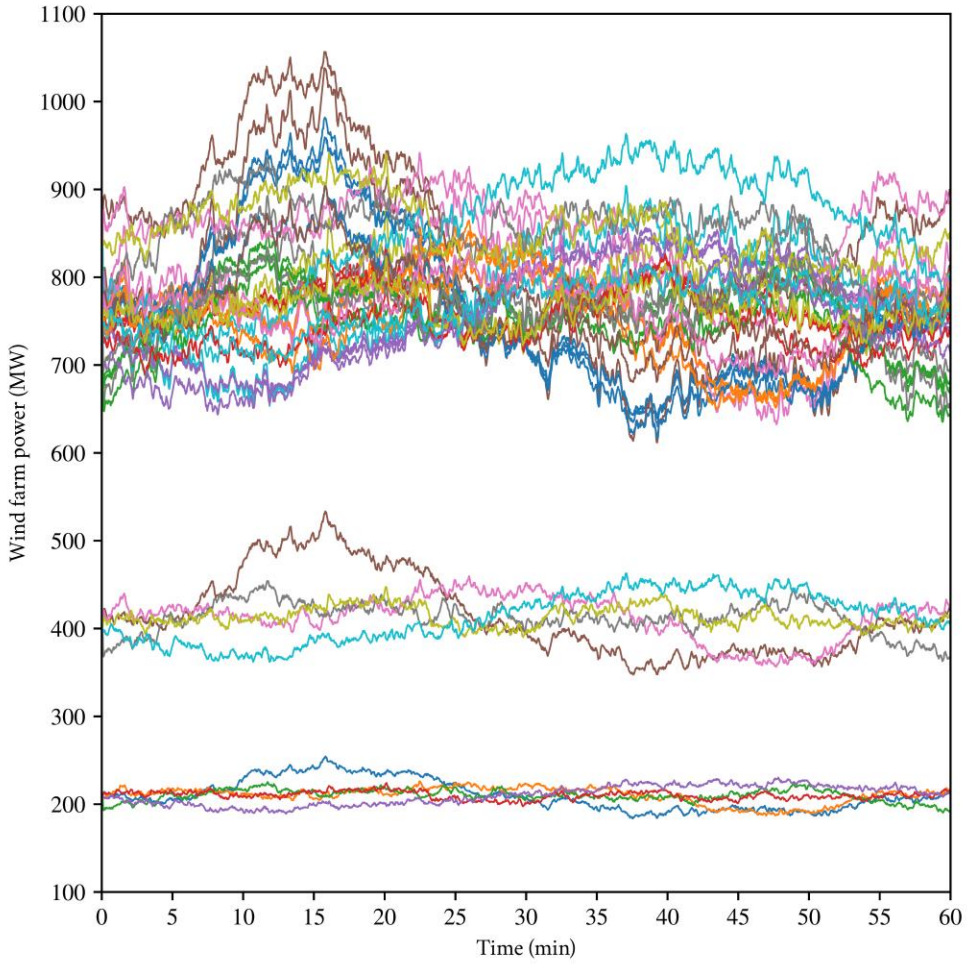
STATCOM
12 MVA
66 kV
100 MW
120 MVA
100 MW
120 MVA
100 MW
120 MVA
100 MW
120 MVA
PLATFORM P4
PLATFORM P5

Wind Farm
Modelled as Grid Following Controller

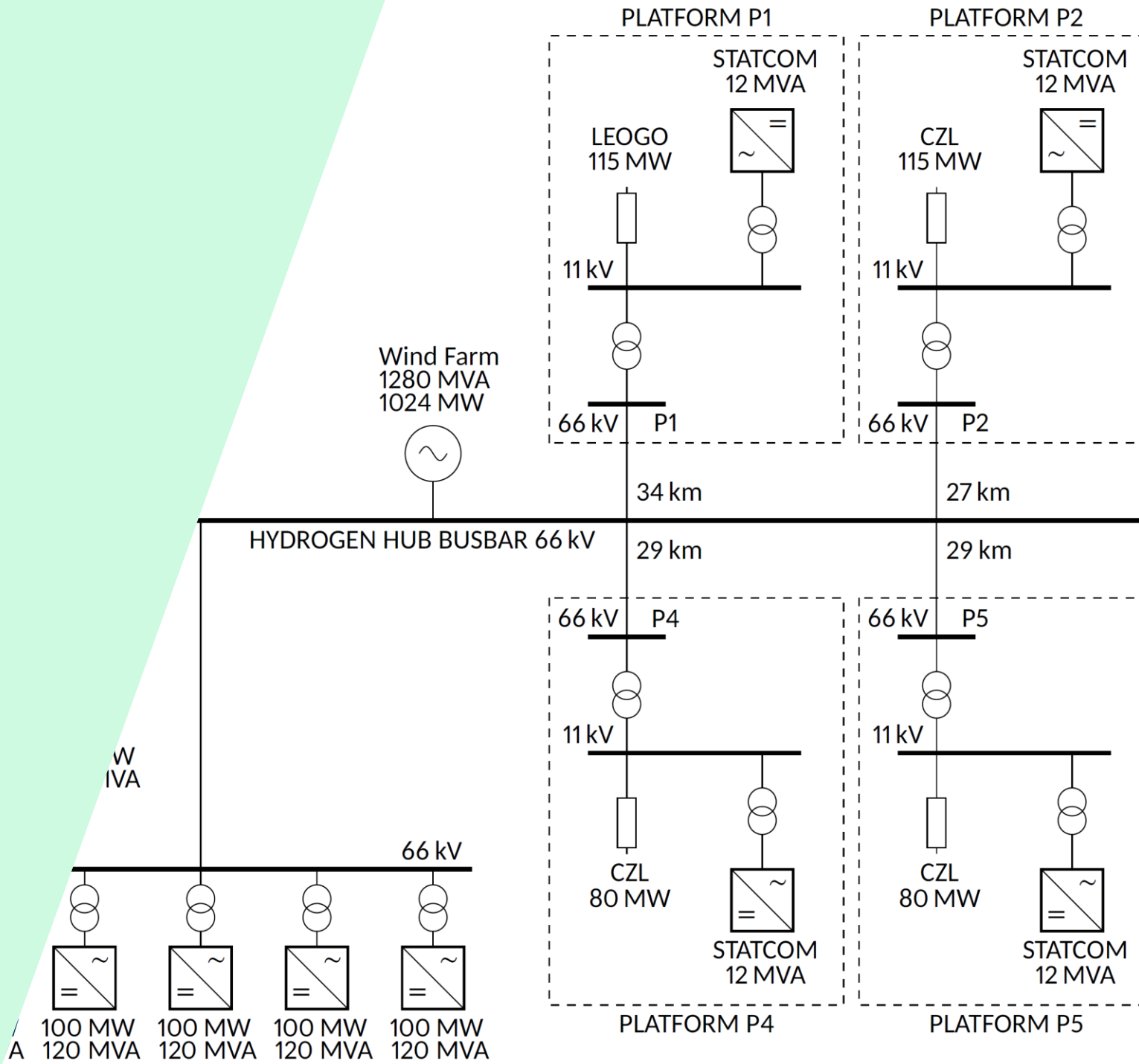
Wind Farm Equivalent





Mota D d S, Haugdal H and Chabaud V 2024 *Journal of Physics: Conference Series* **2875** ISSN 1742-6596 DOI 10.1088/1742-6596/2875/1/012008

STATCOM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STATCOM
12 MVA
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115 MW
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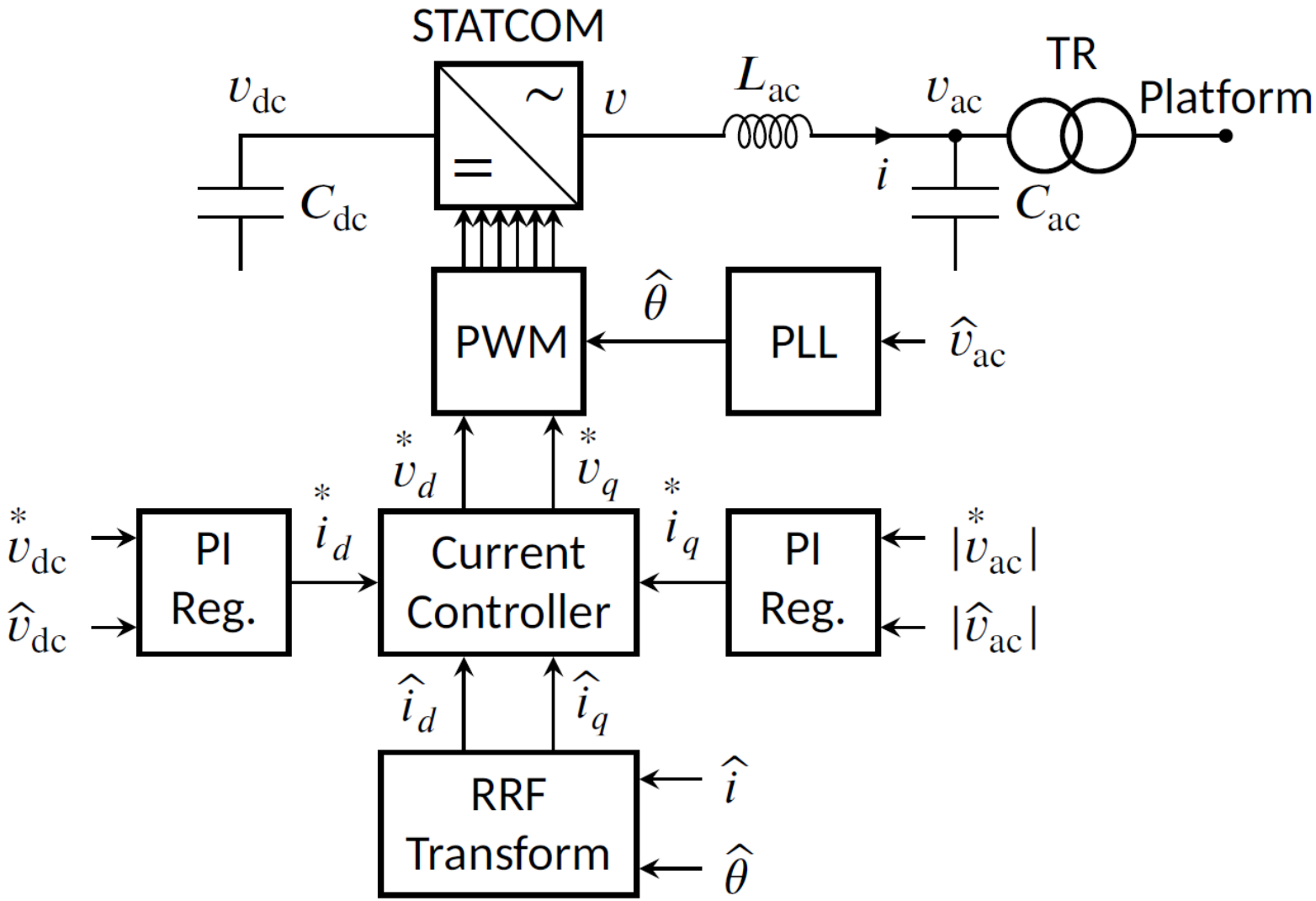
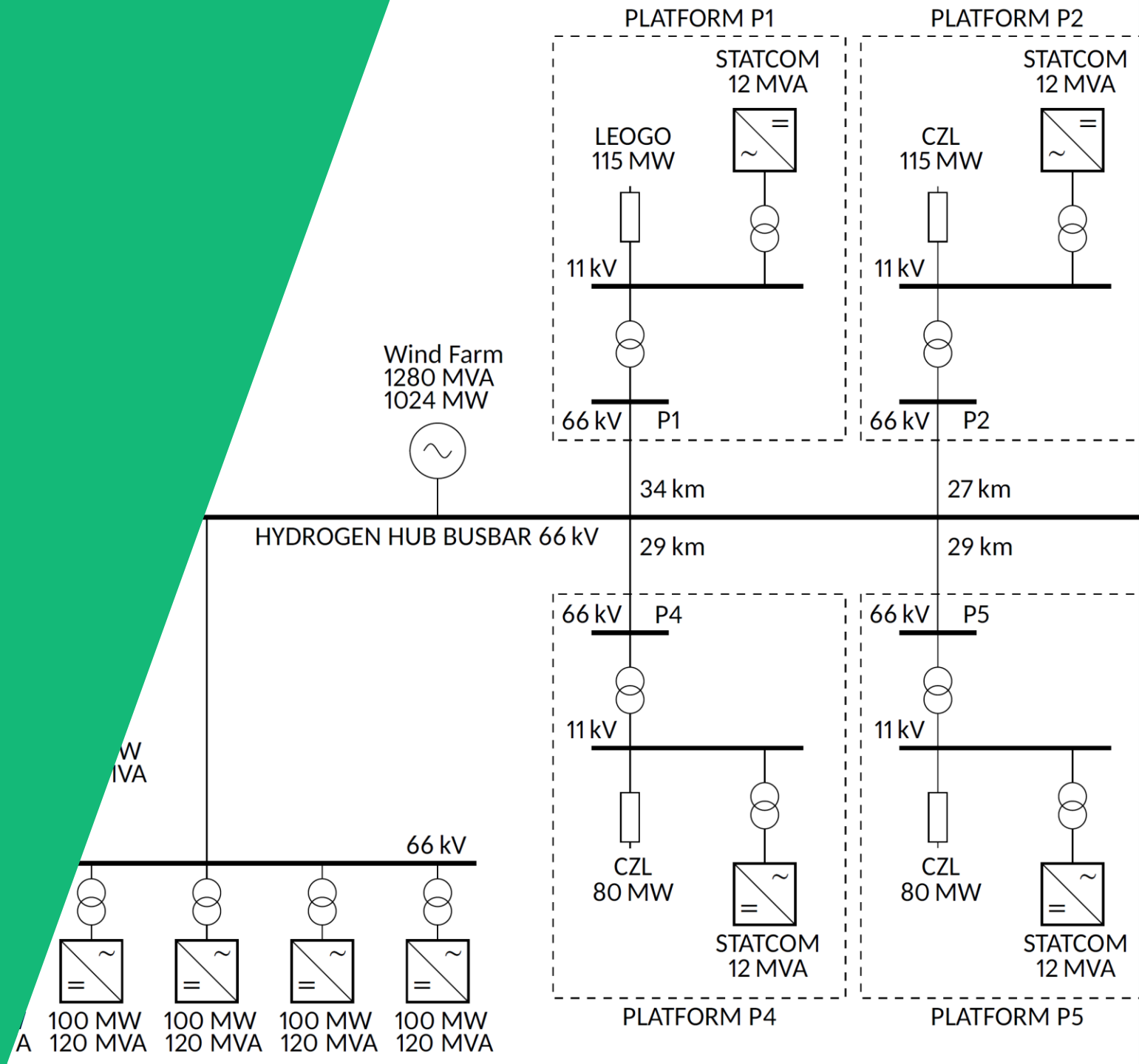
12 MVA
STATCOM
12 MVA
66 kV
100 MW
120 MVA
100 MW
120 MVA
100 MW
120 MVA
100 MW
120 MVA
PLATFORM P4
PLATFORM P5

STATCOM
Grid Following with Voltage Support

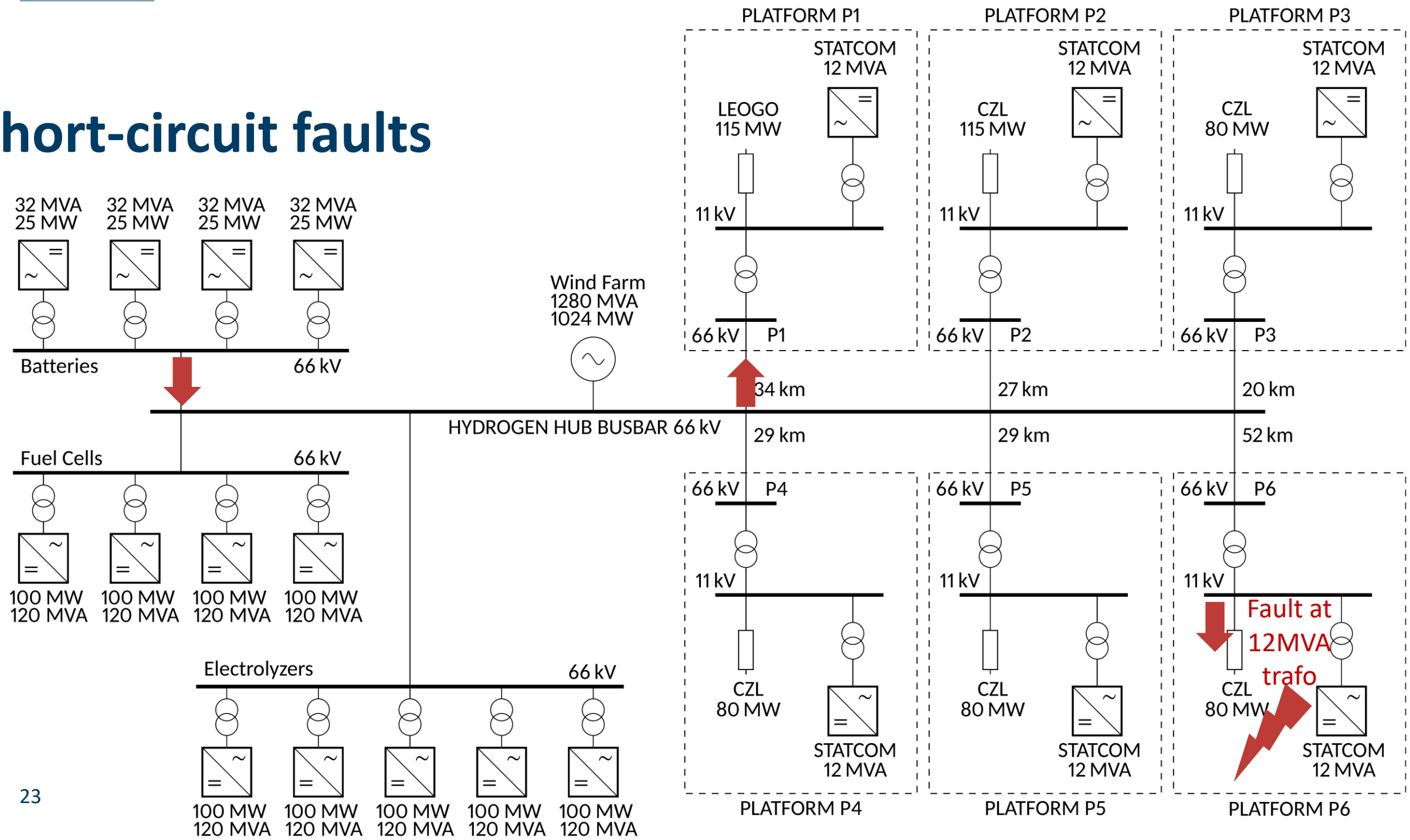


- Provides voltage and reactive power support

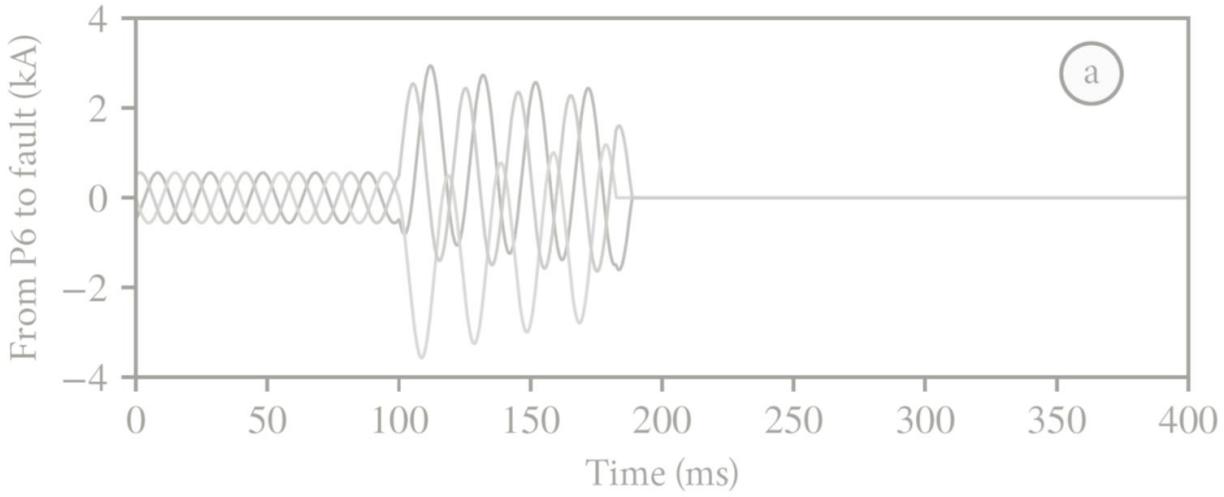
SIMULATION RESULTS

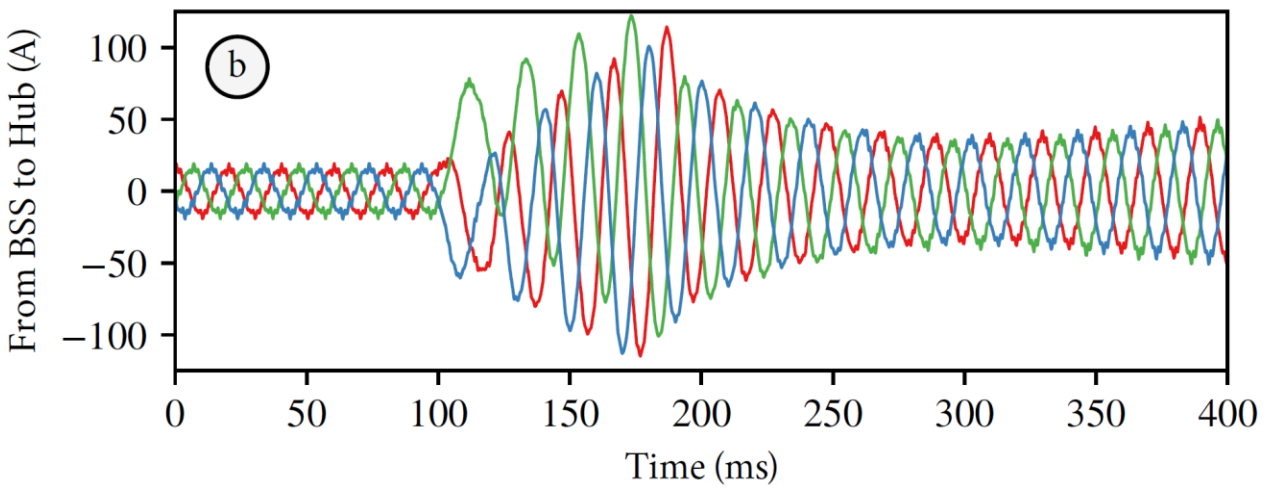


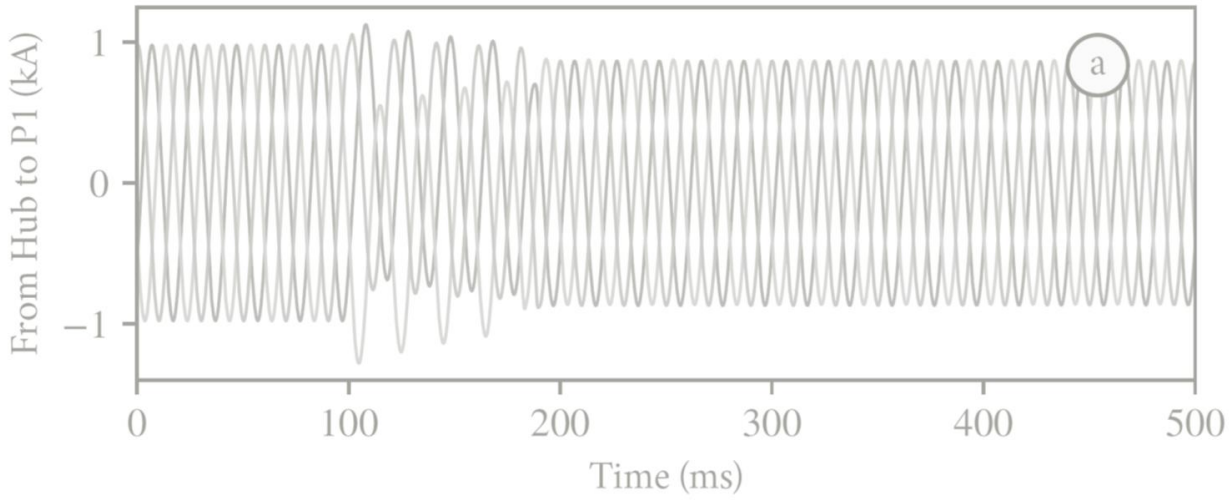
Short-circuit faults



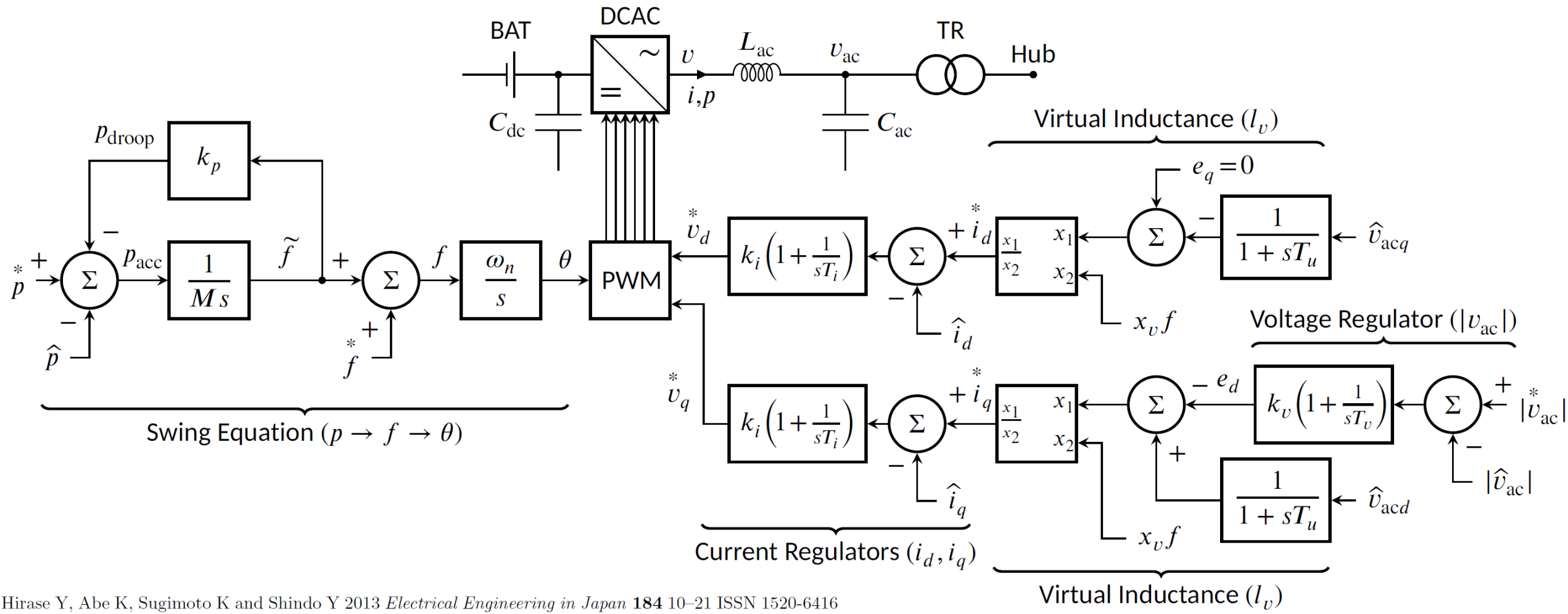
Short Circuit at P6
Currents at different points of the grid







How the short-circuit affects the behaviour of the VSMs



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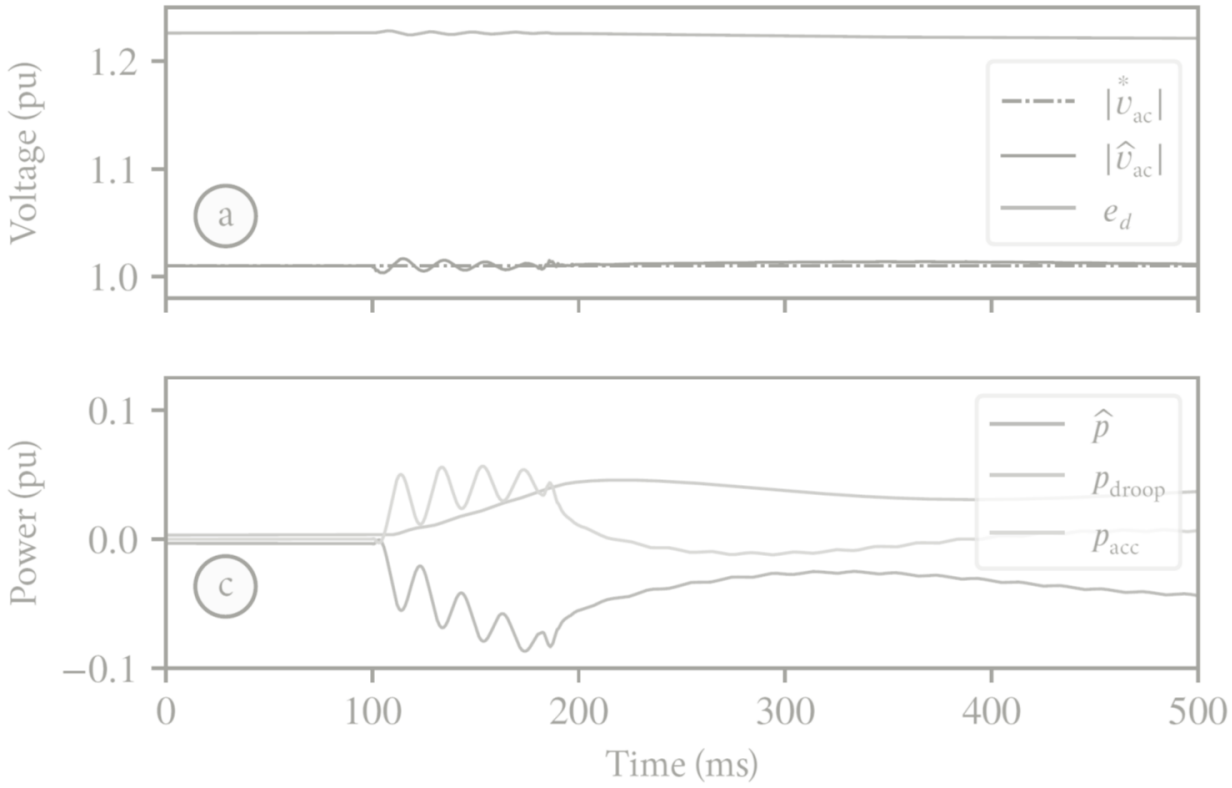
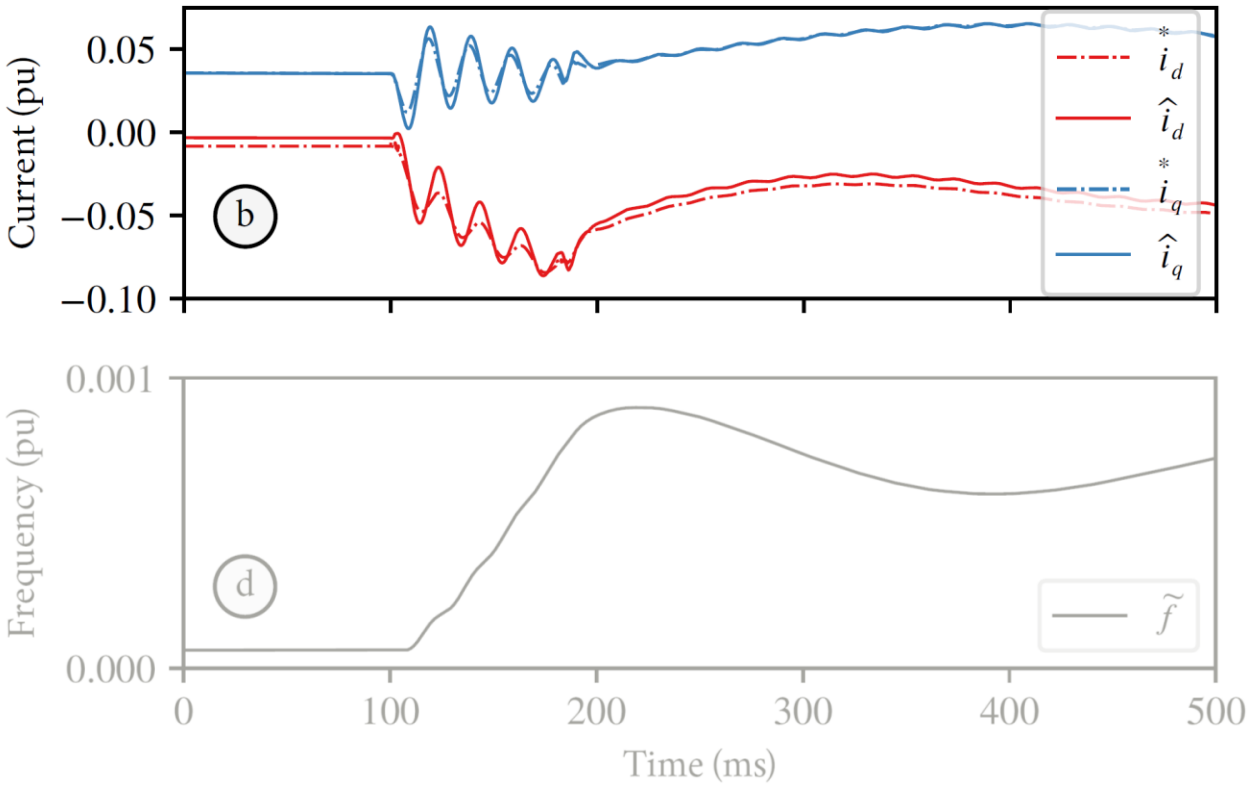
VSM Dynamics During the Short Circuit at P6

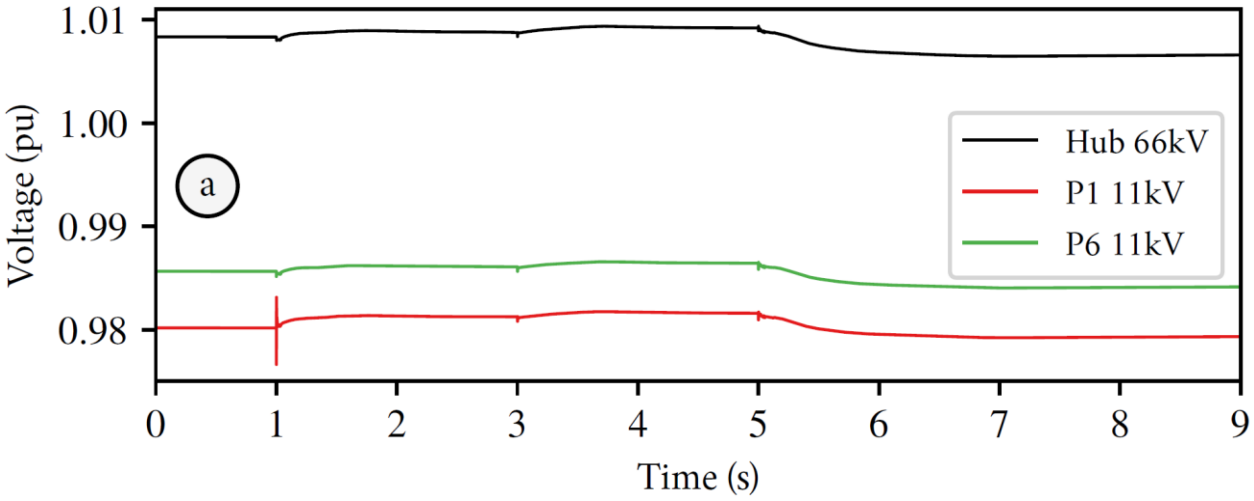
100Hz oscillations due to exponentially decaying DC components

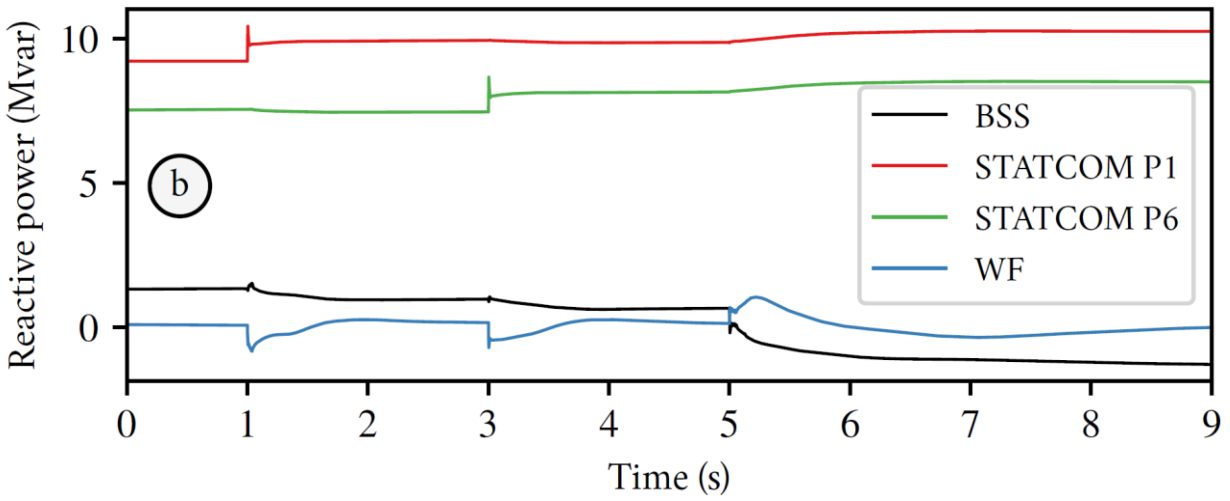




Voltage and Reactive Power Dynamics

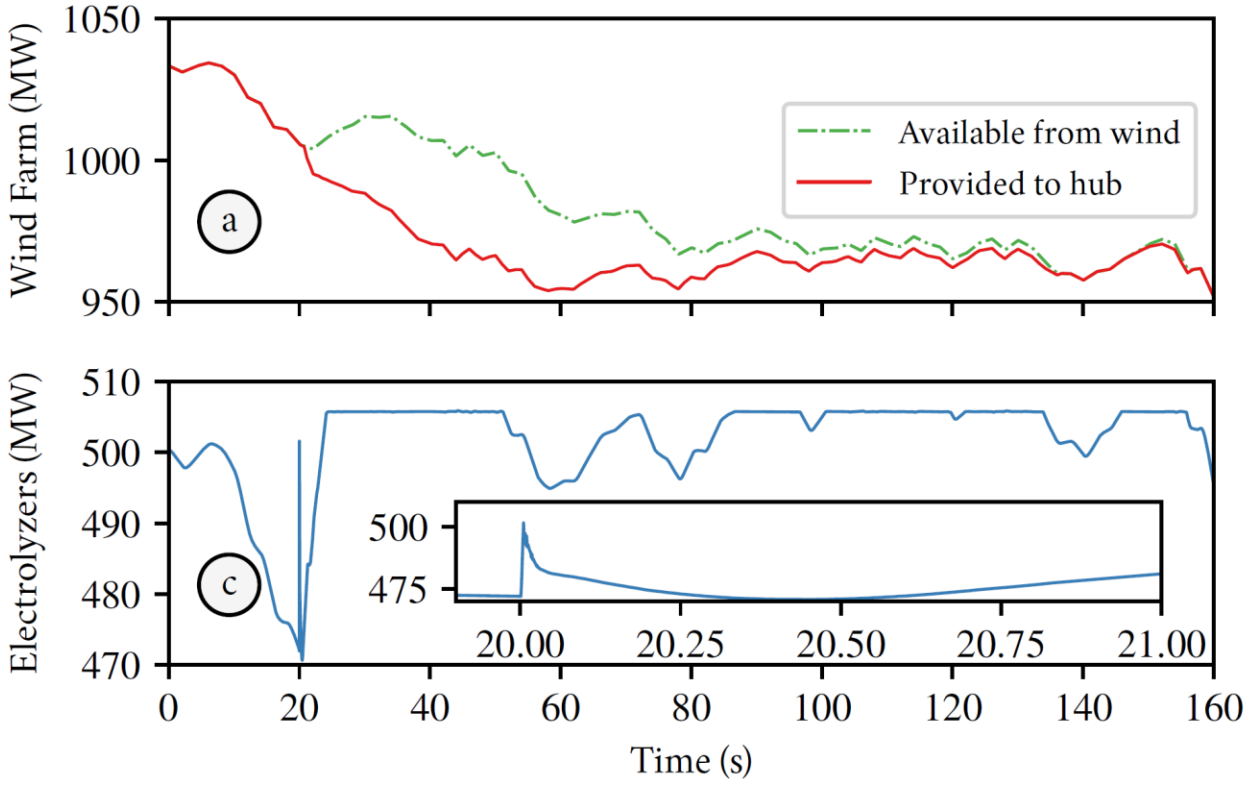
- Wind variations can be “stopped” for isolating specific dynamics

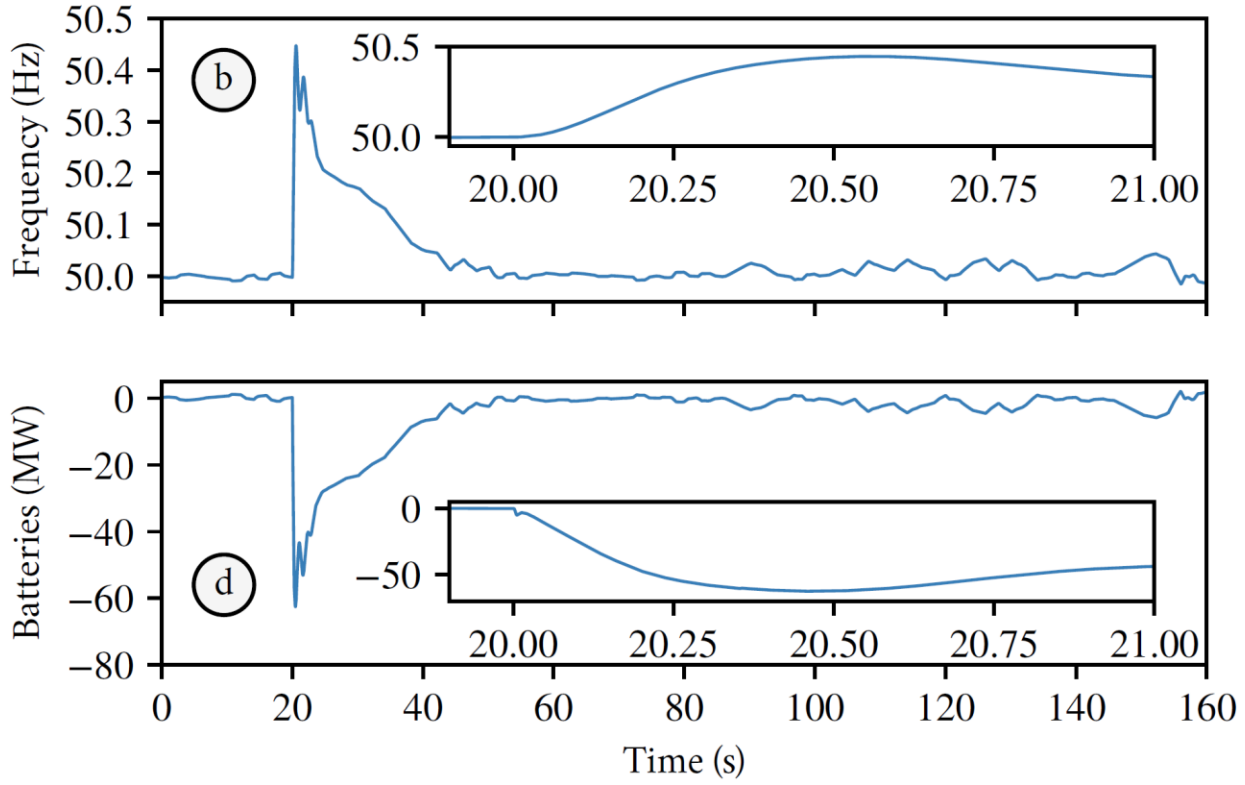




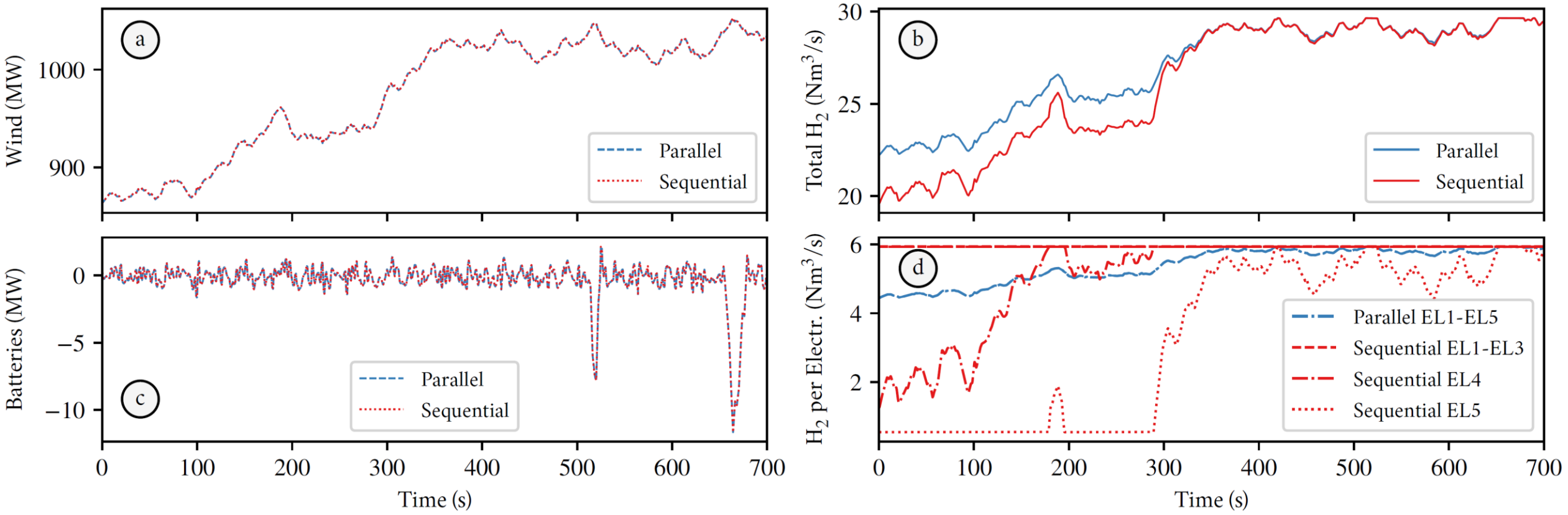
Fast Transients (Load Disconnections) and Wind Curtailment

- Dynamics on the hundreds of seconds, down to milliseconds





Hydrogen Production Dispatching Strategies



Final Remarks

Final Remarks

Electromagnetic transient model of a grid-forming energy hub fed by wind power for an offshore platform cluster

- Includes sophisticated structure for the VSM with current limiters
- Multiple time scales:
  - Fast transients occurring within milliseconds
  - Dynamics of VSMs and secondary reserves over longer periods
  - Wind farm fluctuations over time frames from minutes to hours

Thank you!

Daniel Mota
Researcher
SINTEF Energy Research
Energy Systems

SINTEF

Technology for a better society