Robust Fault-tolerant Control for the Electrical Drive of Airborne Wind Energy Systems

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ALU, Freiburg

Outline

- Introduction
  - Preliminary info
  - Education
  - Previous experience
- AWESCO ITN H2020
  - Electrical drive
  - Facts about conventional wind towers
  - Facts about electrical drives
  - Motivation and objectives
  - Results
  - TUM Laboratory
  - Secondments
- Conclusions

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Introduction

Preliminary info

- Name: Hisham Eldeeb
- Nationality: Egyptian
- Age: 26
- PhD starting date: 01.09.2015
- Affiliation: TU Munich (TUM)
- Position: Research Associate / AWESCO PhD candidate
- Research group: Control of Renewable Energy Systems (CRES)
- Research interests: Power electronics, electrical drives, grid-connected converters, power quality, smart grids

Introduction
Education

- B.Sc. in Electrical Engineering, Alexandria University, Egypt (2006-2011)
  - Thesis: Design and Control of Power Electronic Converters employed for PV-Systems
  - Award: 3rd Best graduation project among faculties of electrical engineering in Egypt, 2011.

- M.Sc. in Electrical Engineering, Alexandria University, Egypt (2012-2014)
  - Thesis: A Stationary Frame Current Control of Inverter-Based Distributed Generation Systems

Introduction
Previous Experience

- Teaching Assistant, Pharos University, Alexandria, Egypt (2012-2013)

- Research Assistant, Texas A&M University, Doha, Qatar (Feb. 2013 – July 2013)

- Research Associate, Qatar University, Doha, Qatar (Feb. 2013 – Jun. 2015)
  - 1.4M$ project for the 2022 FIFA World Cup in Qatar
  - Partners: Qatar University, Texas A&M University in Doha, Spiretronic LLC in USA
  - Grid-connected converters, sensorless control, passive filter design, and flywheel energy storage systems
  - Outcomes:
    - Collaborative network
    - 7 IEEE Conference Papers, 1 Journal (under review)
    - 1 Patent (to be filed in 2016)

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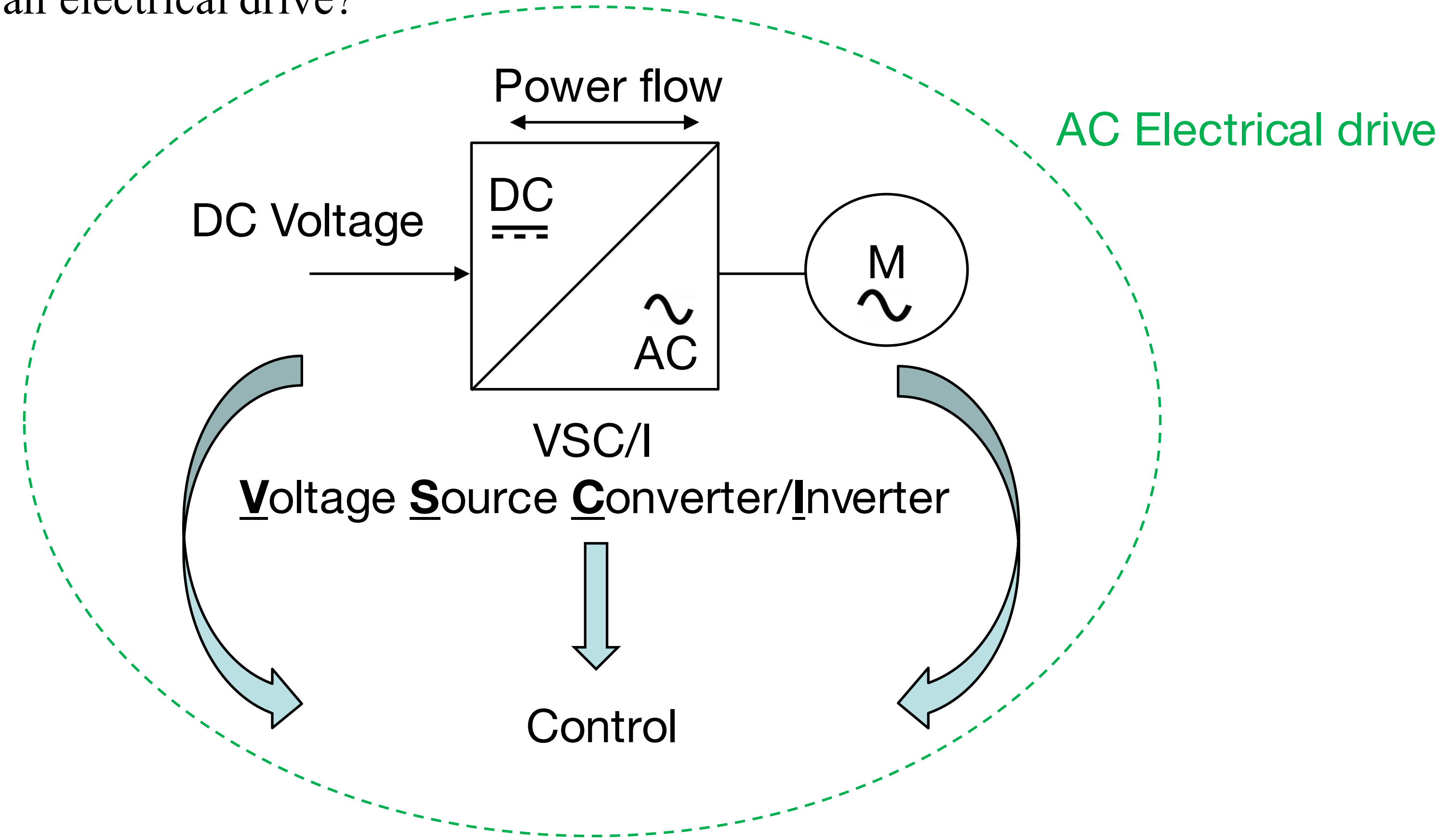
Electrical drive

- What is an electrical drive?



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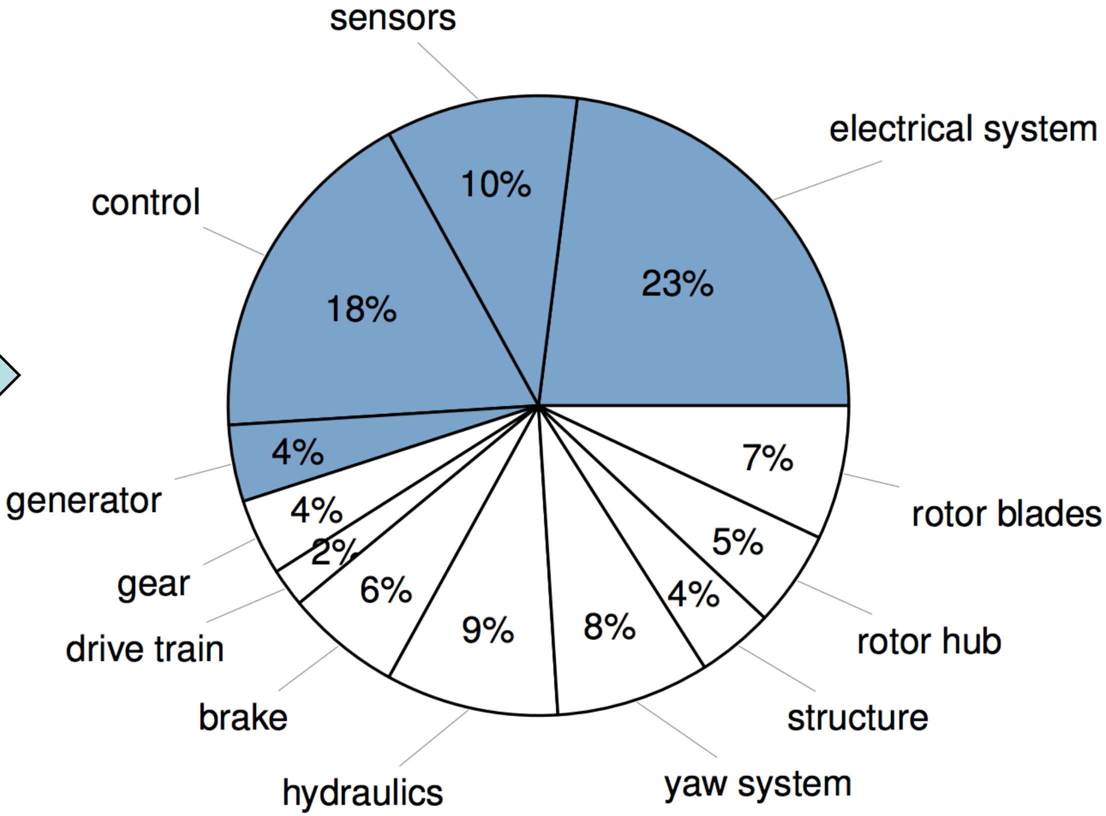
Facts about conventional wind towers

- Wind tower subsystems‘ share of failure [1]



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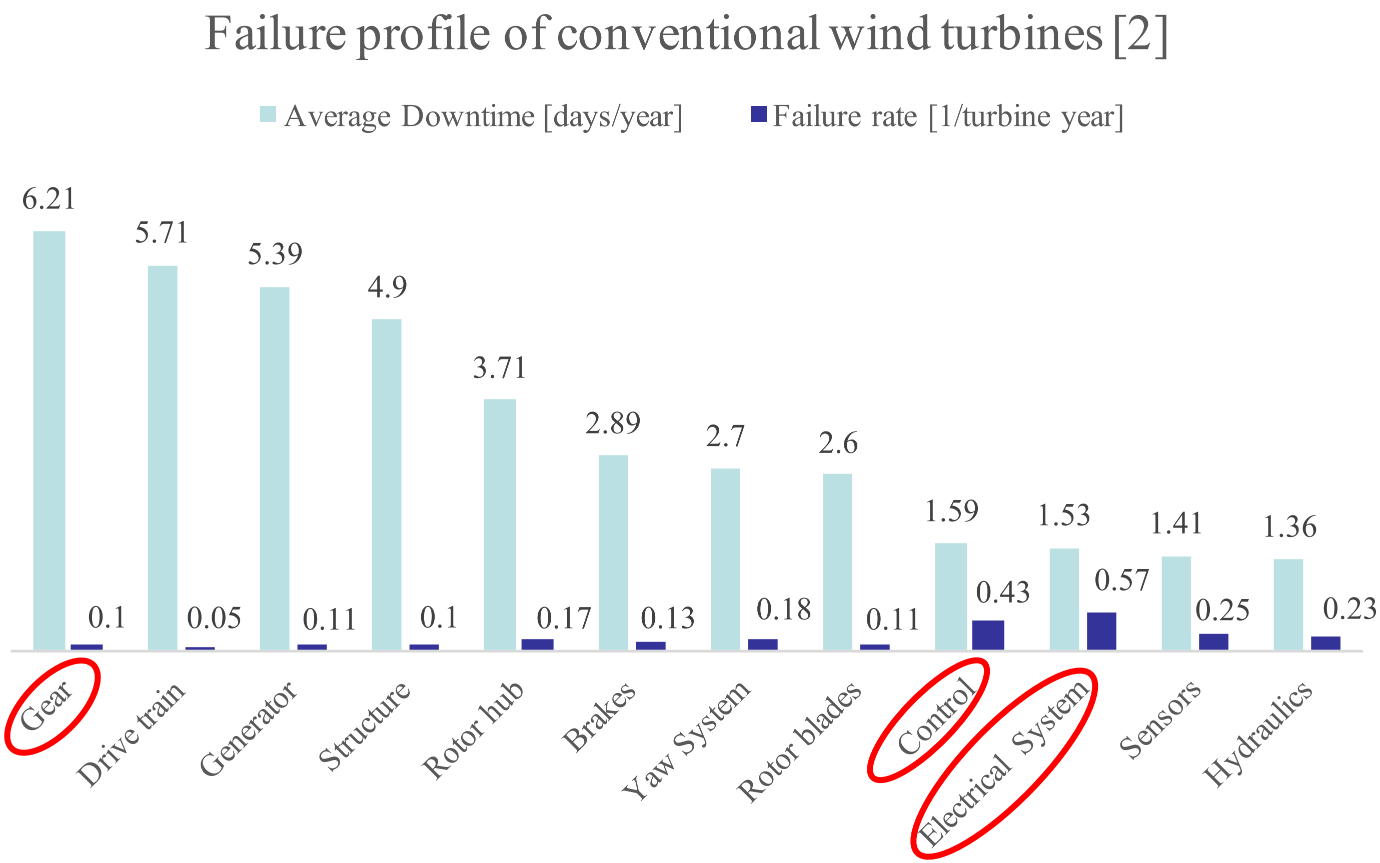
Facts about conventional wind towers



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Facts about conventional wind towers

- Average down time (over 20 years):
  - Gears: 13,6 days
  - Electrical system: 18,9 days
  - Control: 16,7 days

(http://www.youtube.com/watch?v=0Chtr76jJyA)

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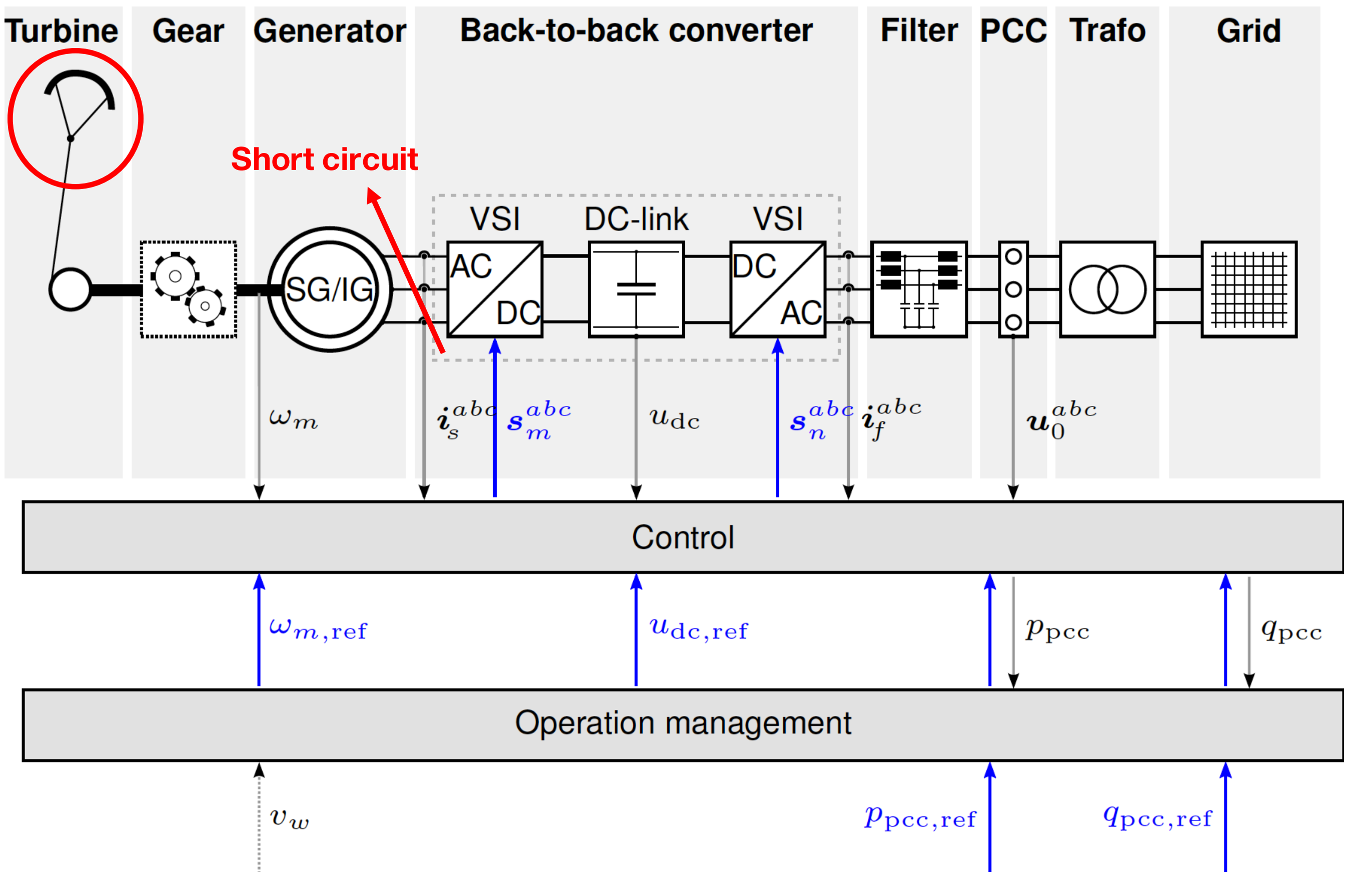
Facts about electrical drives



Block diagram indicating the low-level components of AWE

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Motivation and objectives

- Robust fault-tolerant control of the electrical drive adopted for a direct drive Kite-generation station
- Efficiency enhancement of the direct drive during normal operation
  - H. Eldeeb, J. Kullick, C. Hackl, L. Horelbeck
  - Simulation results (success)
    - Efficiency improvement
    - Rapid execution
    - Concrete convergence
  - Publications:
    - To be submitted TORQUE'16
    - IEEE conference paper (in progress)
    - IEEE Journal paper (in progress) → Optimised torque control even beyond rated speed
  - Practical validation (In progress)

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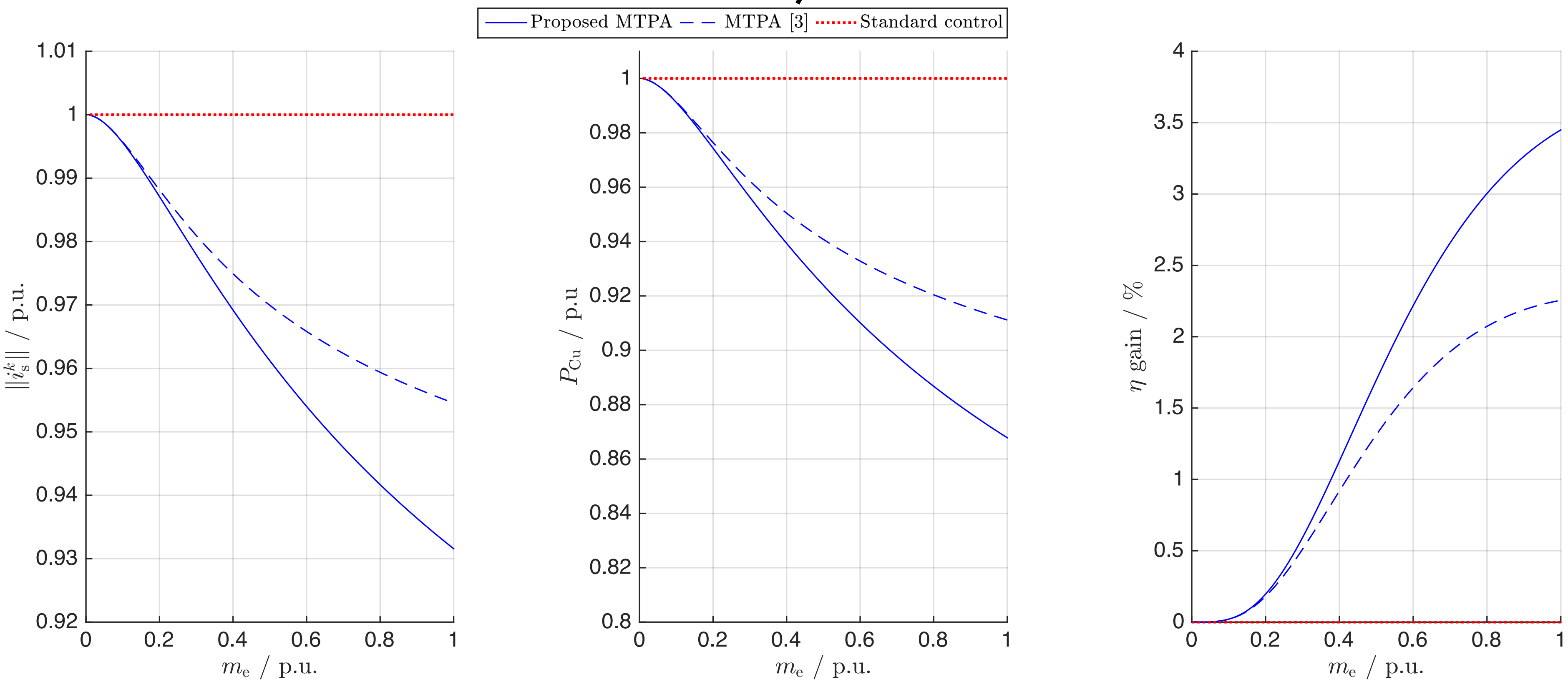
Results

MTPA: **M**aximum **T**orque **p**er **A**mpere



Current magnitude vs torque

Copper losses vs torque

Efficiency gain vs torque

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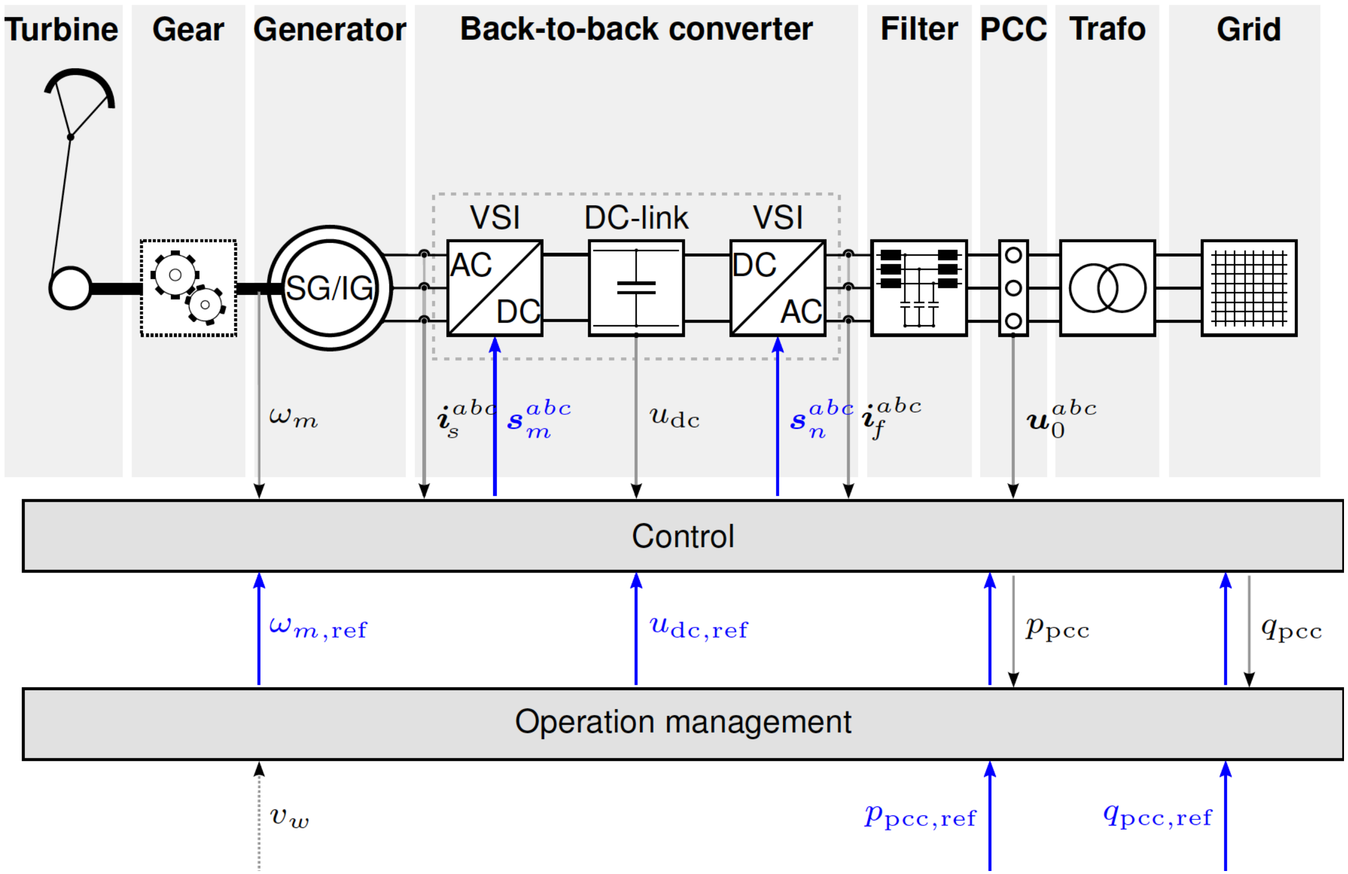

Block diagram indicating the low-level components of AWE

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Test bench of the low-level components of AWE

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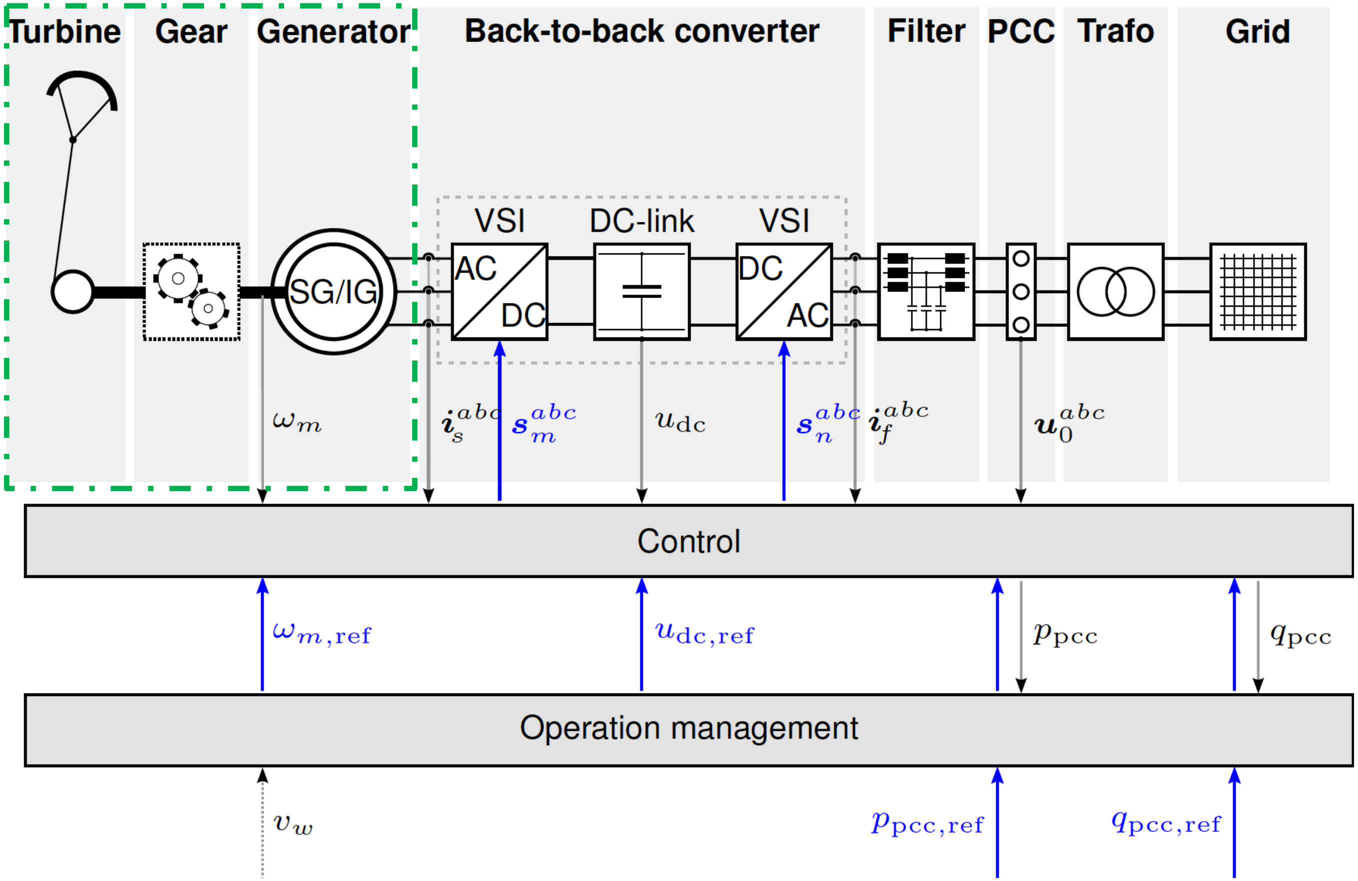

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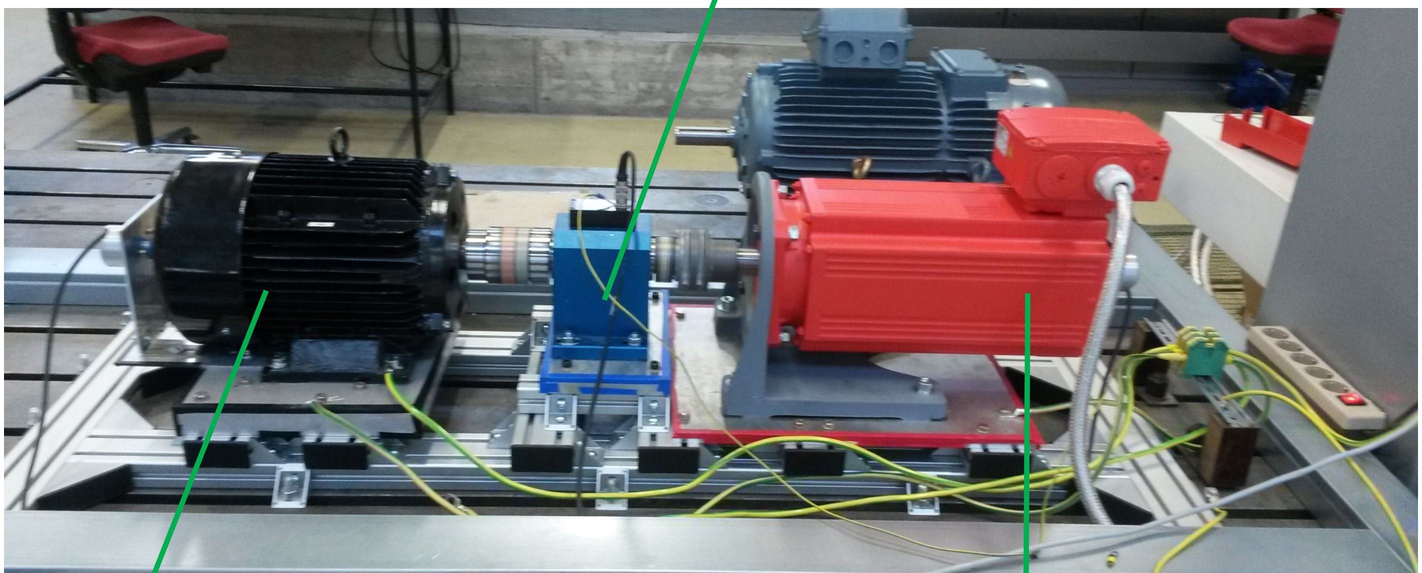
Torque sensor



<u>R</u>eluctance <u>S</u>ynchronus <u>M</u>achine
(RSM: Kite+Gear)
9.6 kW, 61 Nm, 1500 RPM, 3φ, 400 V

<u>P</u>ermanent <u>M</u>agnet SM (PMSM: Generator)
17 kW, 70Nm, 2000 RPM, 3φ, 400 V

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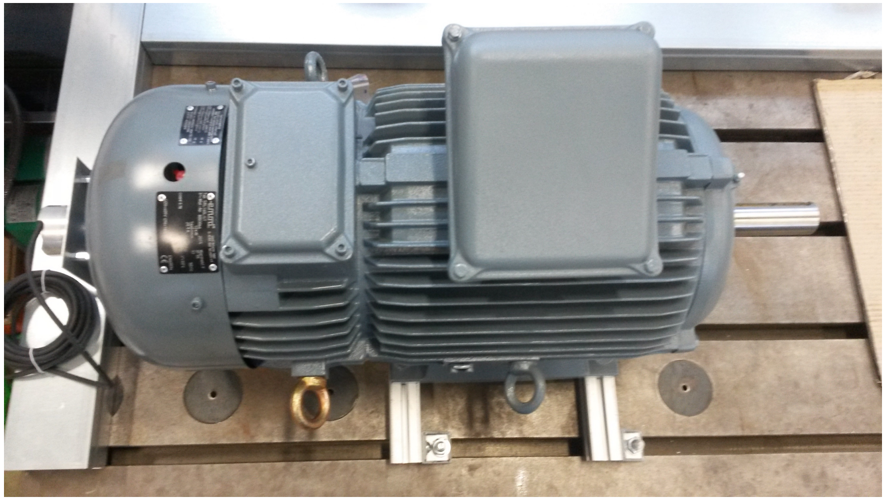
- Possibilities for other generators



Doubly-**F**ed **I**nduction **M**achine (DFIM)
10 kW, 66.5Nm, 1635 RPM, 3φ, 400 V

Electrically **E**xcited **S**ynchronous **M**achine (EESM)
10 kW, 64Nm, 1500 RPM, 3φ, 400 V

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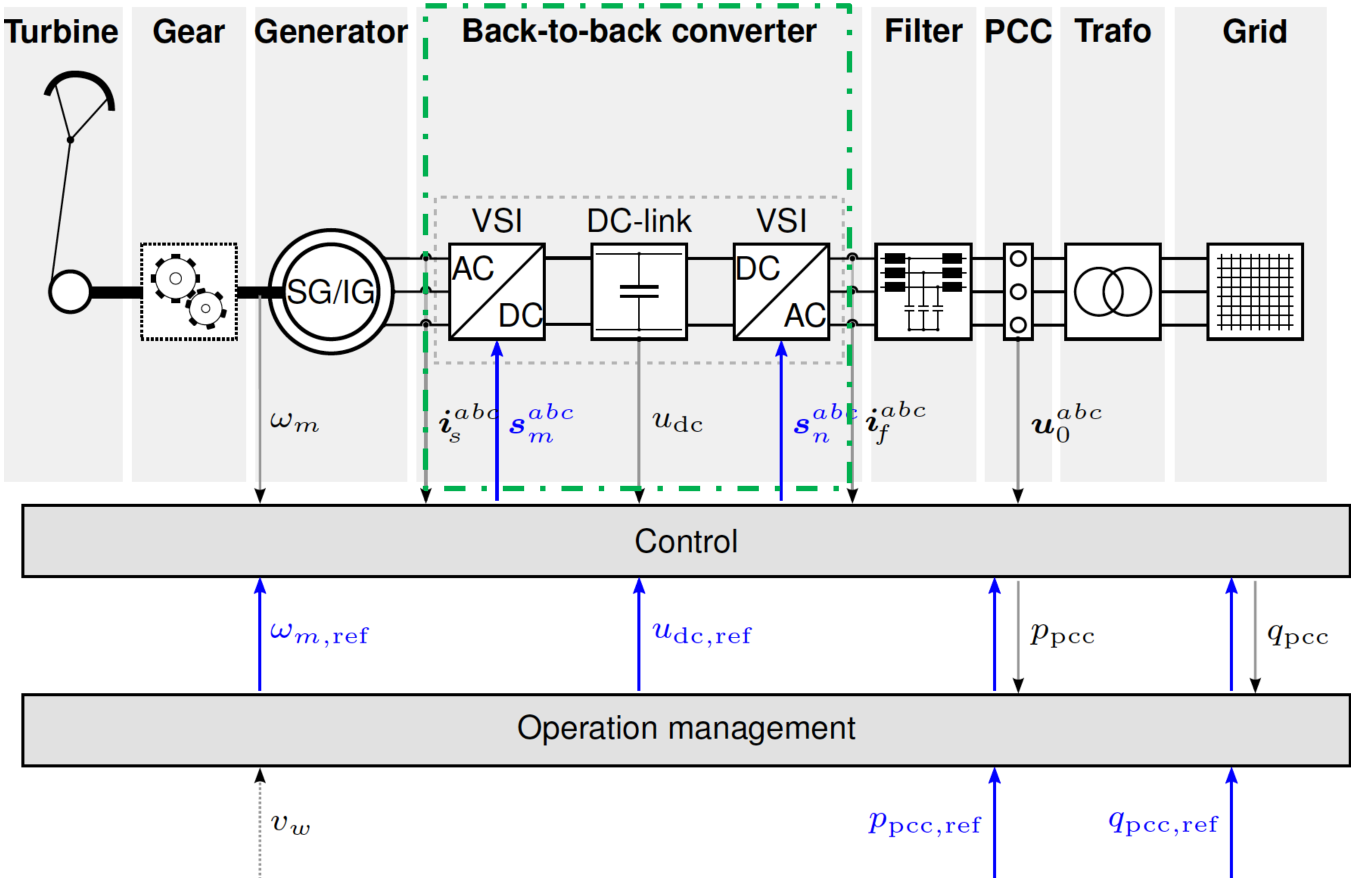

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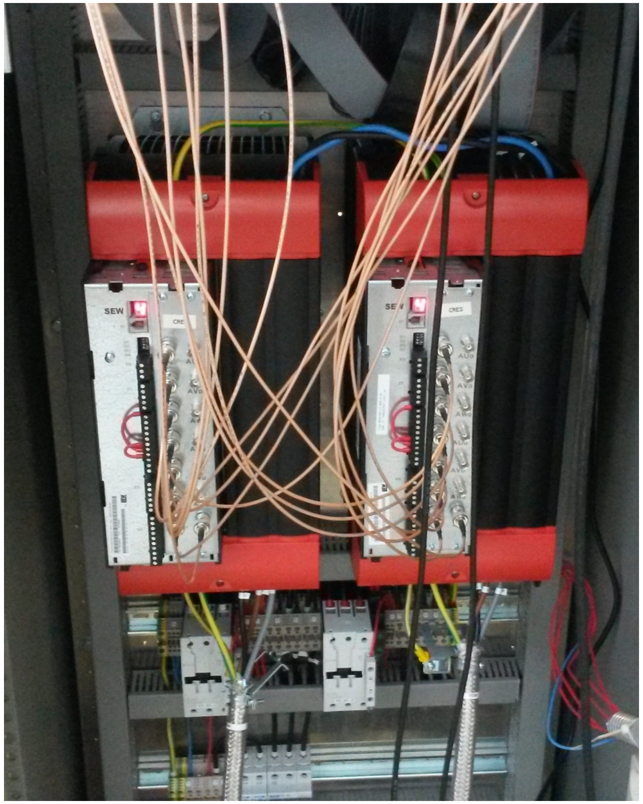

2x VSC 16 kHz, 33 kW, 560 V

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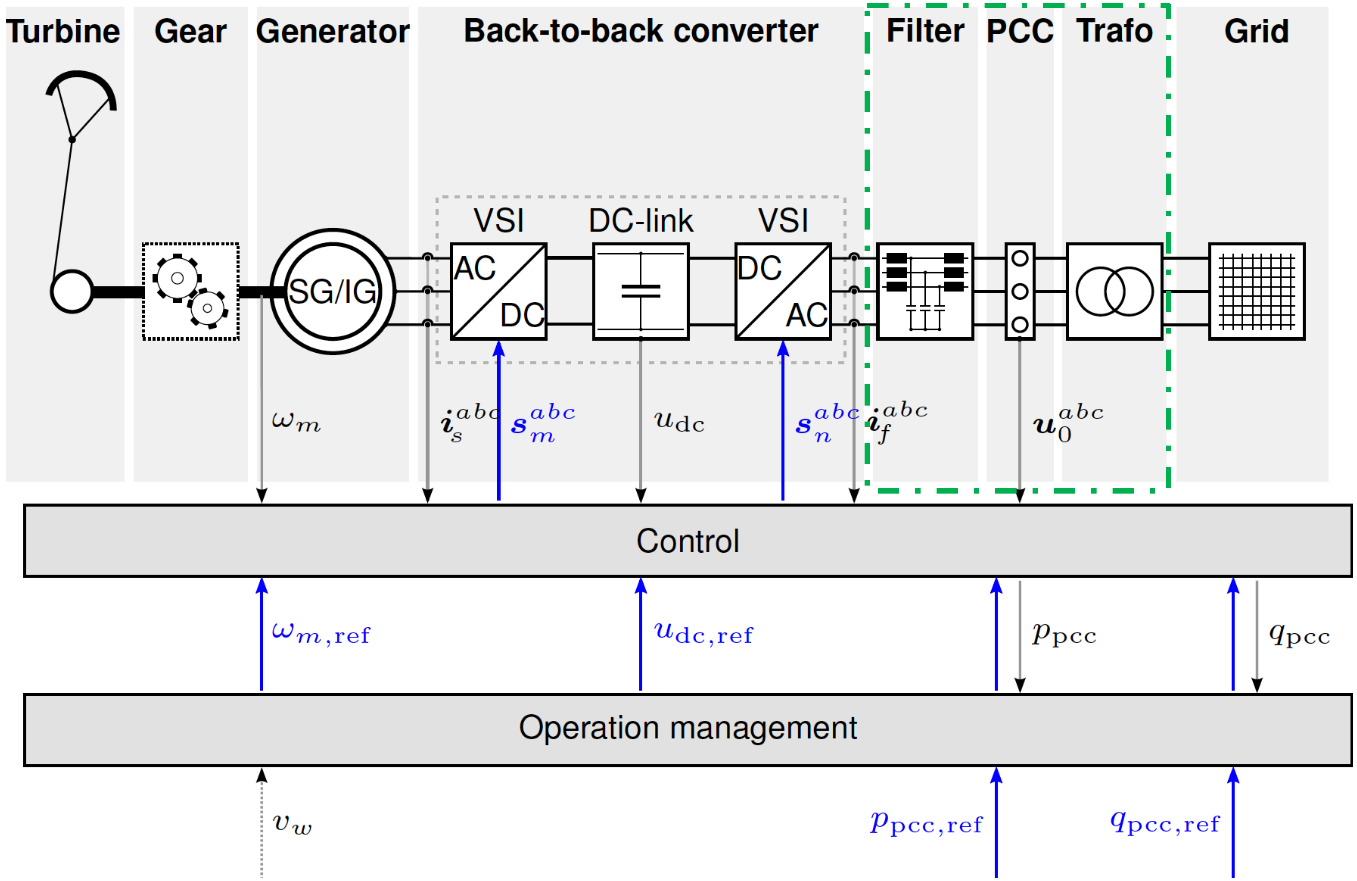

Block diagram indicating the low-level components of AWE

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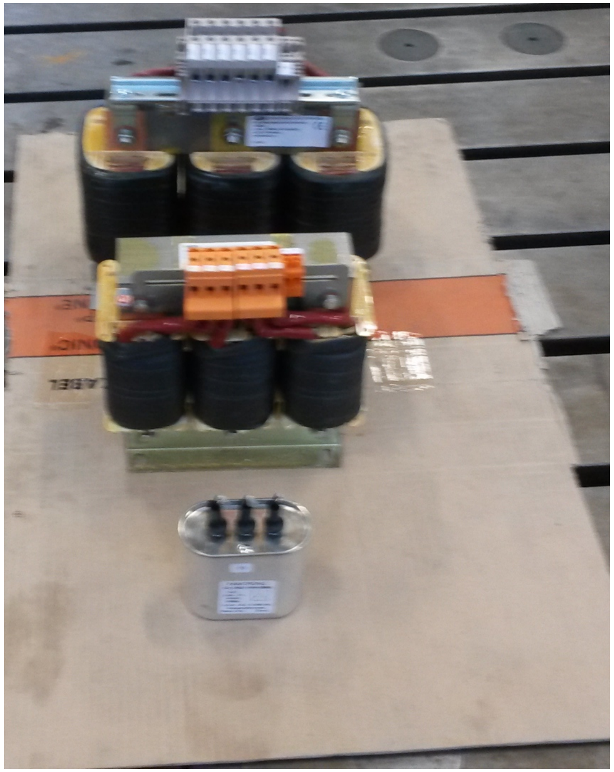

LCL filter
6x 2.5 mH, 3x 10μF

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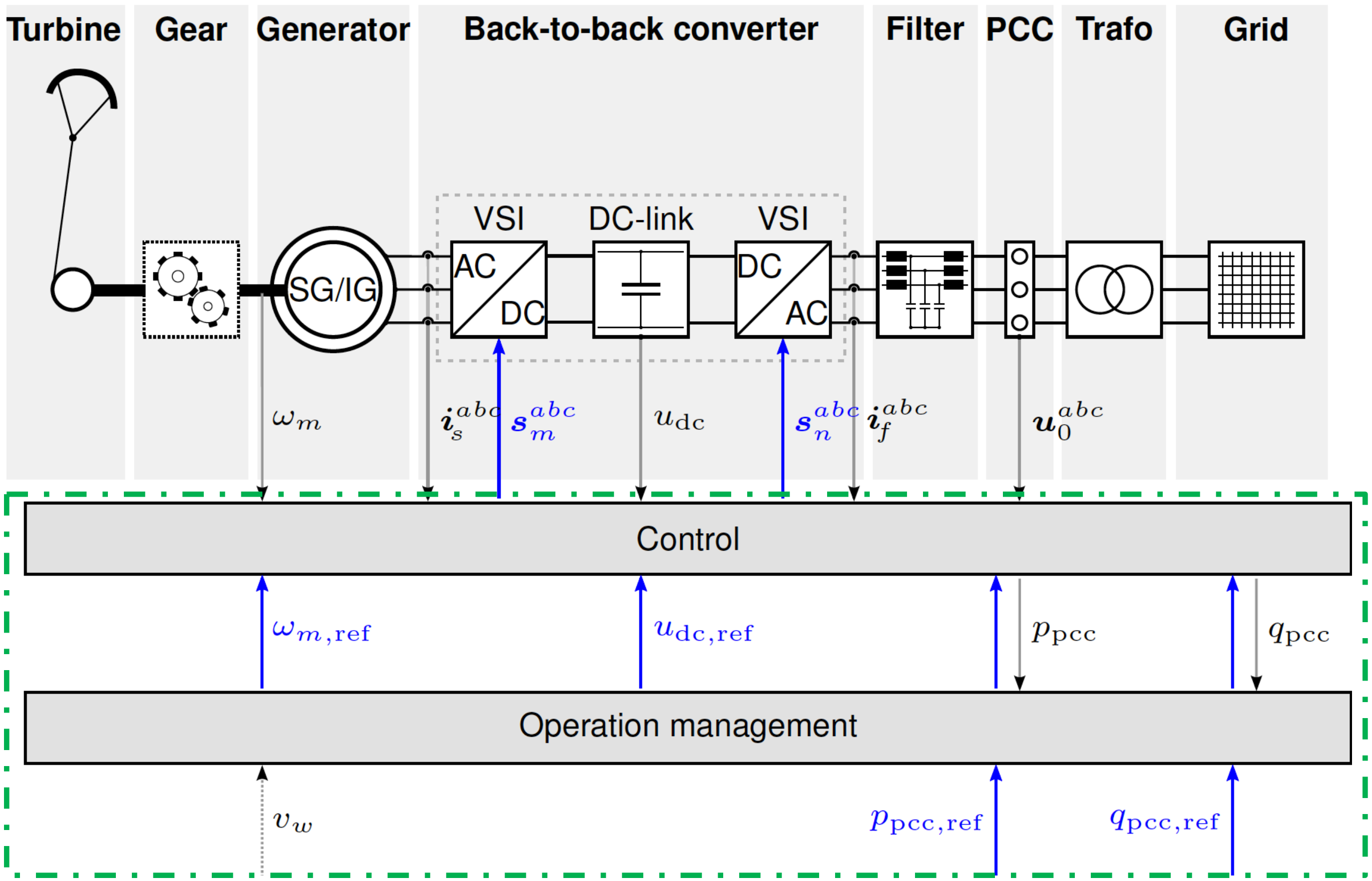

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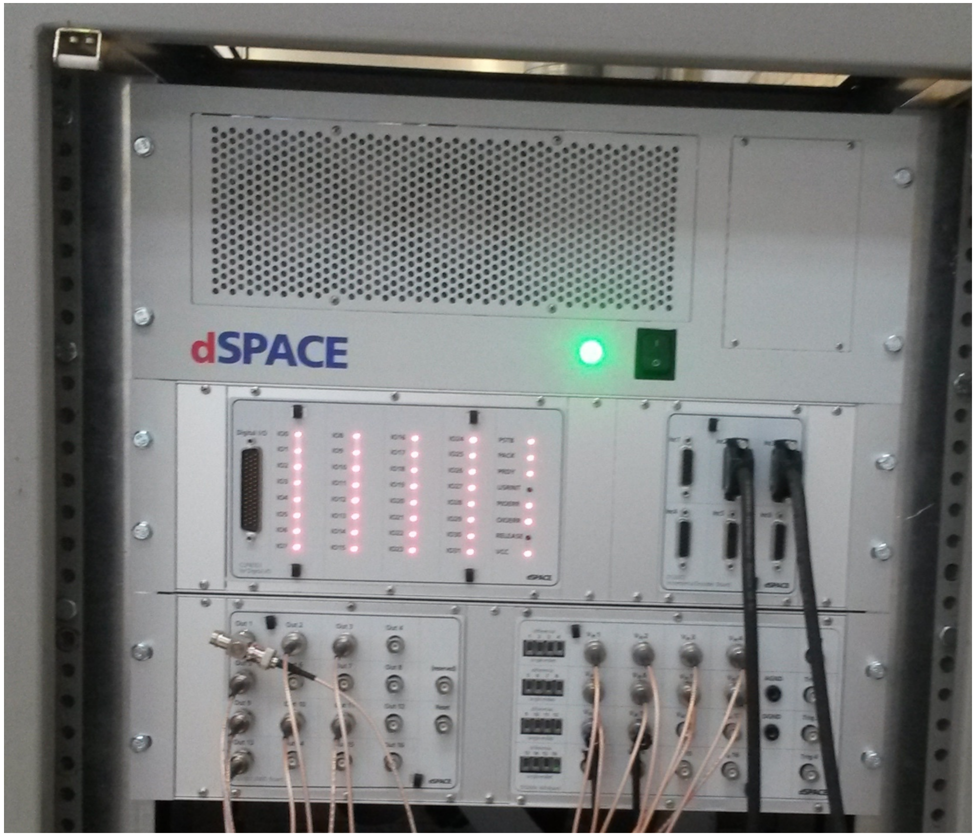

dSPACE DS1007

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Secondments and collaborations

- Committed

Ampyx Power	06.03.2016	03.04.2016
Enerkite	10.04.2016	24.04.2016

- Planned in 2016 (Ampyx Power and Enerkite,)
- Planned in 2017 (Chalmers University)
- Collaboration with ALU

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Conclusions

- Electrical drives are an intermediate stage between the kite and the grid in AWE
- Conventional solutions for electrical drives during faults are not acceptable
- Research outcomes
  - Robust fault-tolerant control of the direct drive Kite-generator station
  - Efficiency enhancement of the electrical drive during unfaulty conditions
- Collaborations and secondments are sought to adjust and improve the outcomes

References

1. B. Hahn, M. Durstewitz, and K. Rohrig, "Reliability of wind turbines, experiences of 15 years with 1500 WTs," in Wind Energy (J. Peinke, P. Schaumann, and S. Barth, eds.), Proceedings of the Euromech Colloquium, pp. 329–332, Berlin: Springer-Verlag, 2007.
2. B. T. P. J. Faulstich, S. Hahn, "Wind turbine downtime and its importance for offshore deployment," Wind Energy, vol. 14, pp. 327–337, 2011.
3. M. Preindl and S. Bolognani, "Optimal State Reference Computation With Constrained MTPA Criterion for PM Motor Drives," in *IEEE Transactions on Power Electronics*, vol. 30, no. 8, pp. 4524-4535, Aug. 2015.

THANK YOU!