

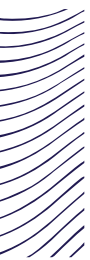


# Modern Power Transmission Systems

Research Program overview & activities (end 2019)



AALBORG UNIVERSITY  
DENMARK



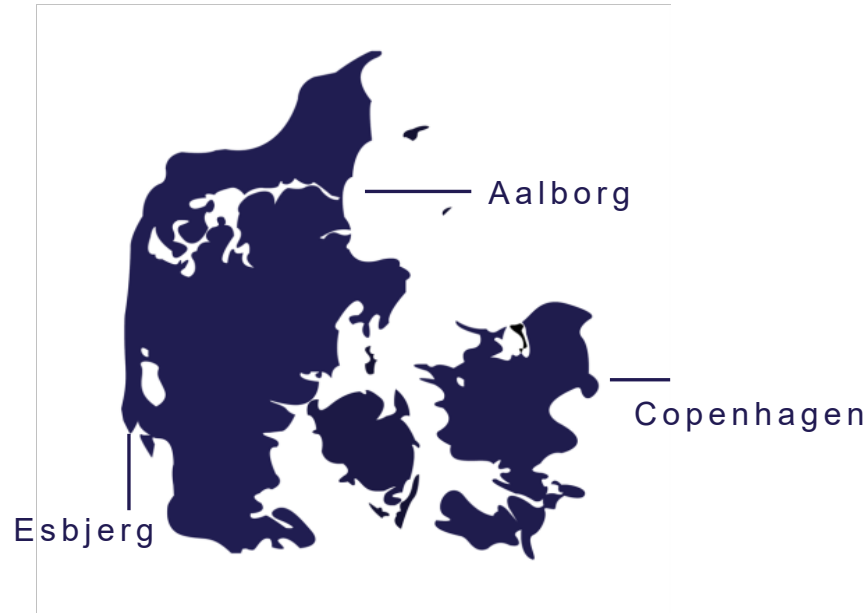
▶ The University

▶ The Department

▶ The Research Group



# AAU Facts



## AALBORG

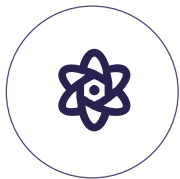
- approx. 19,800 students and approx. 3,300 employees

## KØBENHAVN

- approx. 3,050 students and approx. 340 employees

## ESBJERG

- approx. 500 students and approx. 90 employees



### RESEARCH & EDUCATION

- ▶ Humanities
- ▶ Engineering and Science
- ▶ Medicine
- ▶ Social Sciences
- ▶ IT and Design



### STUDENTS

- ▶ 20,600 students (not part-time)
- ▶ 2,800 part-time students
- ▶ 839 PhD students



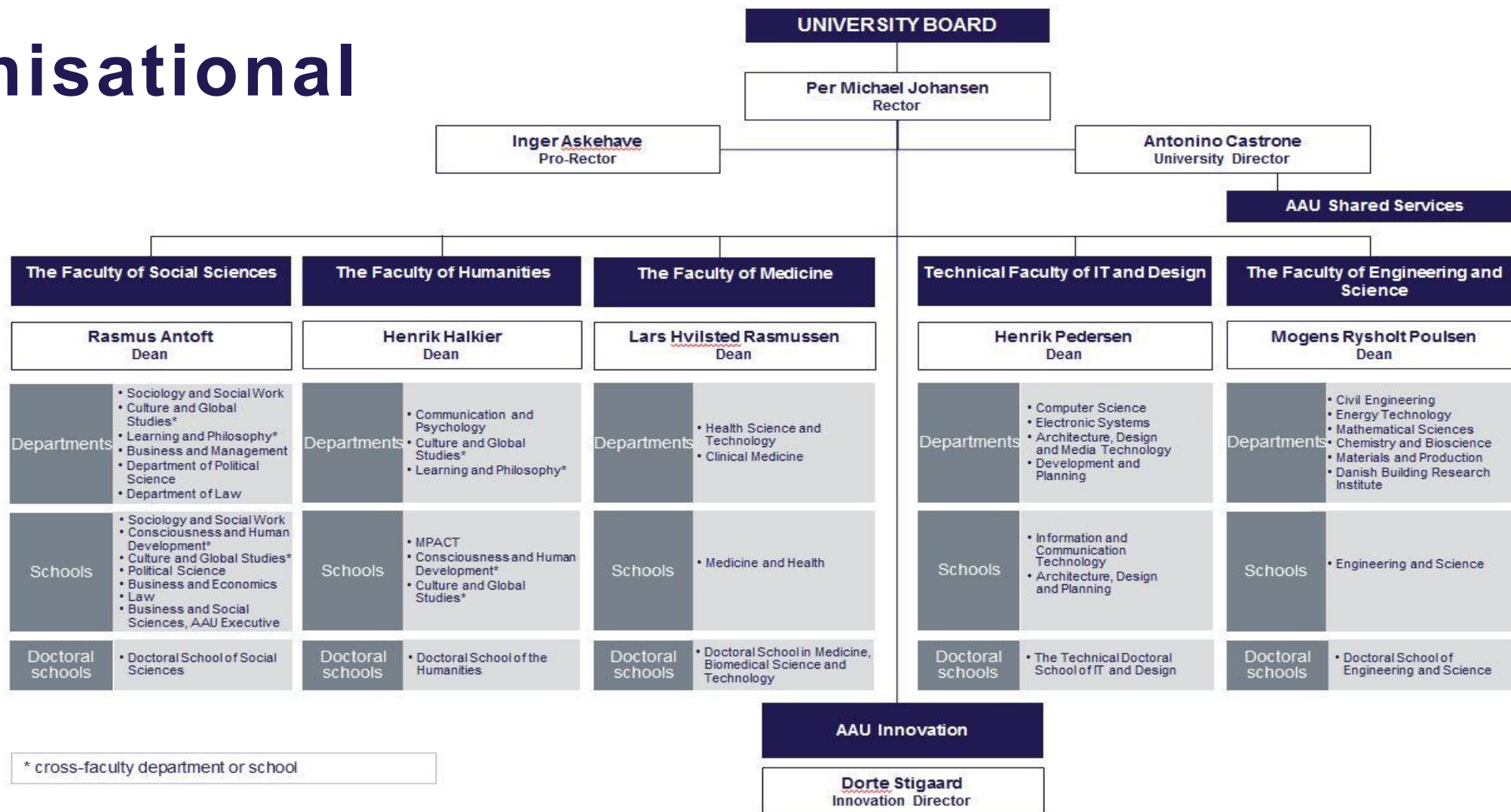
### RESOURCES

- ▶ 2,300 employees in relation to research and education
- ▶ 680 international researchers
- ▶ 1,435 administrative staff
- ▶ Overall budget DKK 2.9 billion

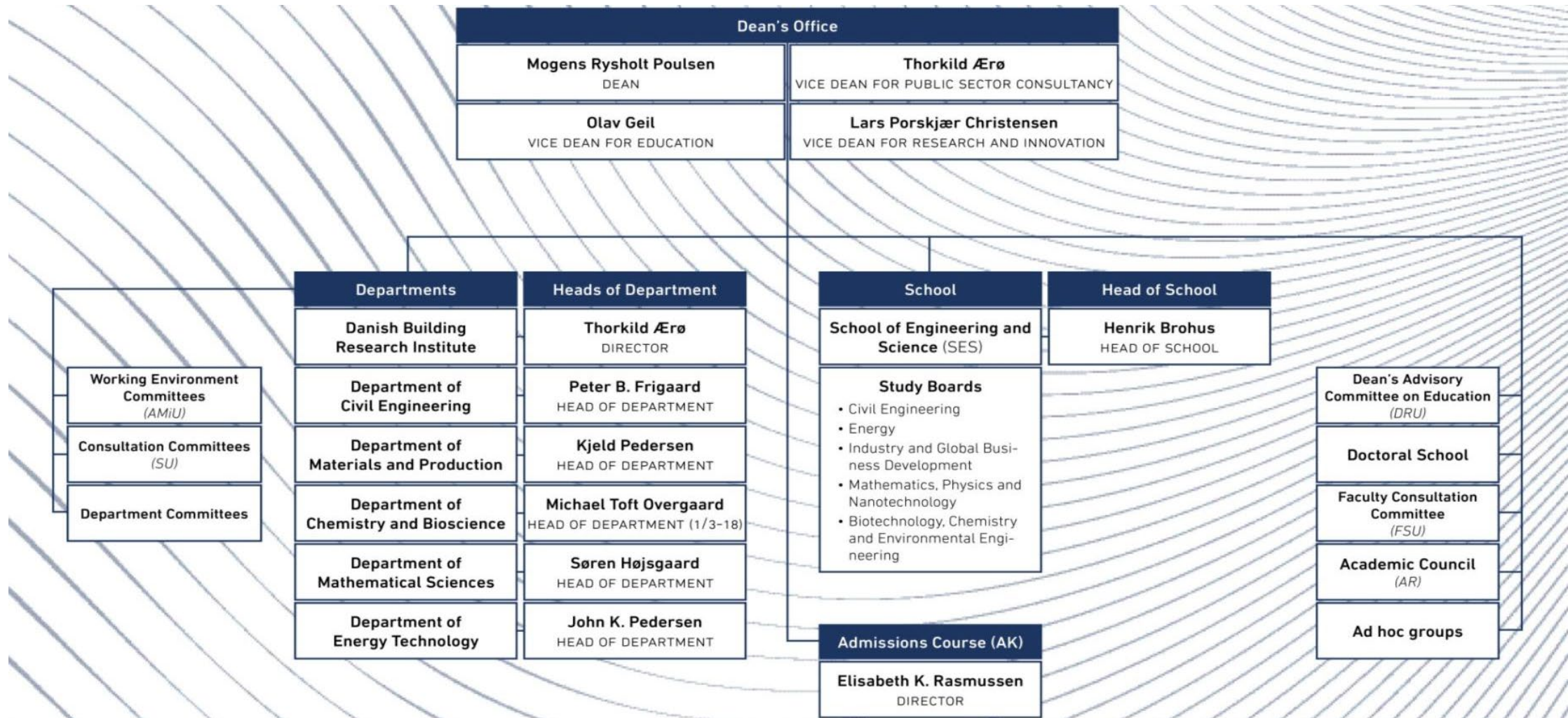




# AAU organisational chart



# Faculty of Engineering and Science



# MIT: Current global leaders in engineering education

- ▶ 50 thought leaders were asked to identify and describe the five or six universities they considered to be the current global leaders in engineering education.
- ▶ In all, 81 universities from 22 countries were identified. The 10 institutions most consistently cited as 'current leaders' are presented.

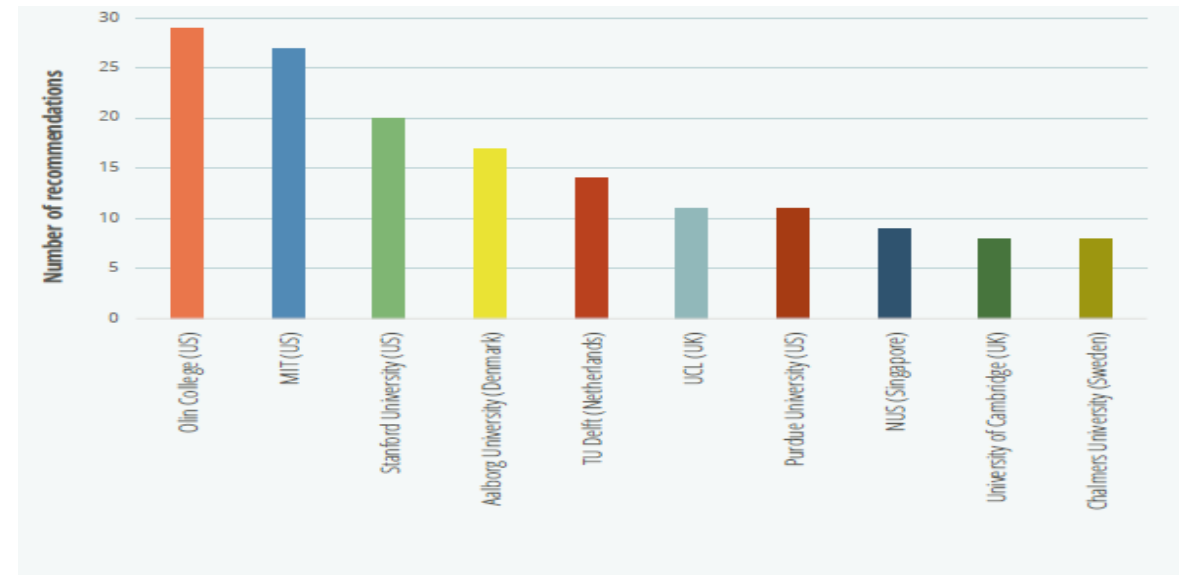


Figure 3. The 10 institutions most frequently identified as 'current leaders' in engineering education

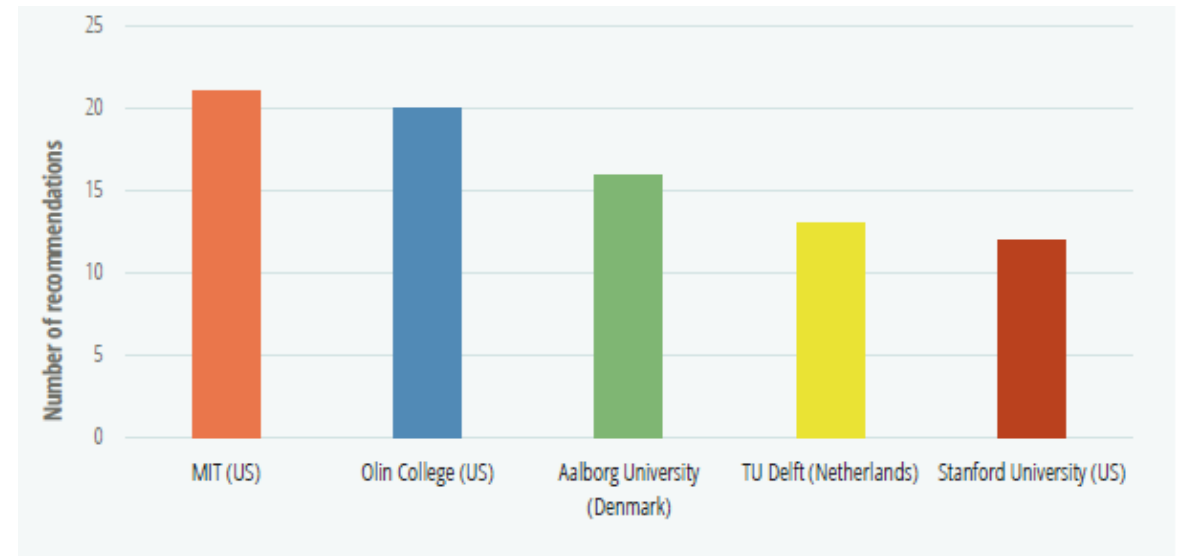


Figure 4. The five institutions most frequently identified as 'current leaders' in engineering education, with the results adjusted for the country of residence of the interviewee



# DANISH UNIVERSITIES ARE LEADING IN THE FIELD OF ENGINEERING



## IN EUROPE:

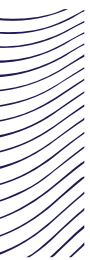
- 1 AAU - Aalborg University (Denmark)
- 2 Imperial College London (United Kingdom)
- 3 Swiss Federal Institute of Technology Zurich (Switzerland)
- 4 École Polytechnique Federale of Lausanne (Switzerland)
- 5 Delft University of Technology (Netherlands)
- 6 DTU - Technical University of Denmark (Denmark)

## GLOBALLY:

- 1 Tsinghua University (China)
- 2 National University of Singapore (Singapore)
- 3 MIT - Massachusetts Institute of Technology (USA)
- ⋮
- 8 AAU - Aalborg University (Denmark)
- ⋮
- 24 DTU - Technical University of Denmark (Denmark)

Best Global Universities, U.S. News and World Report, 2018





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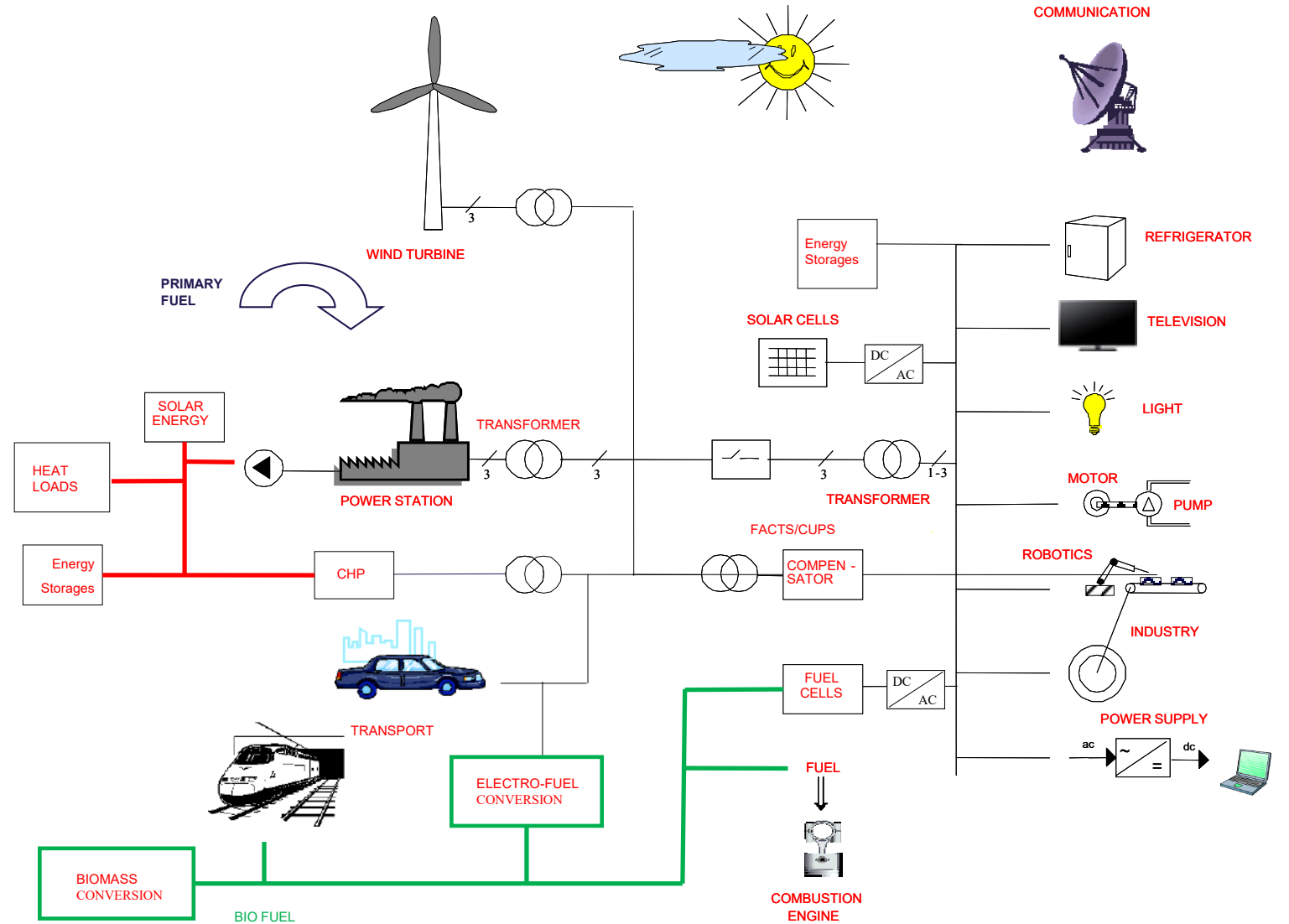




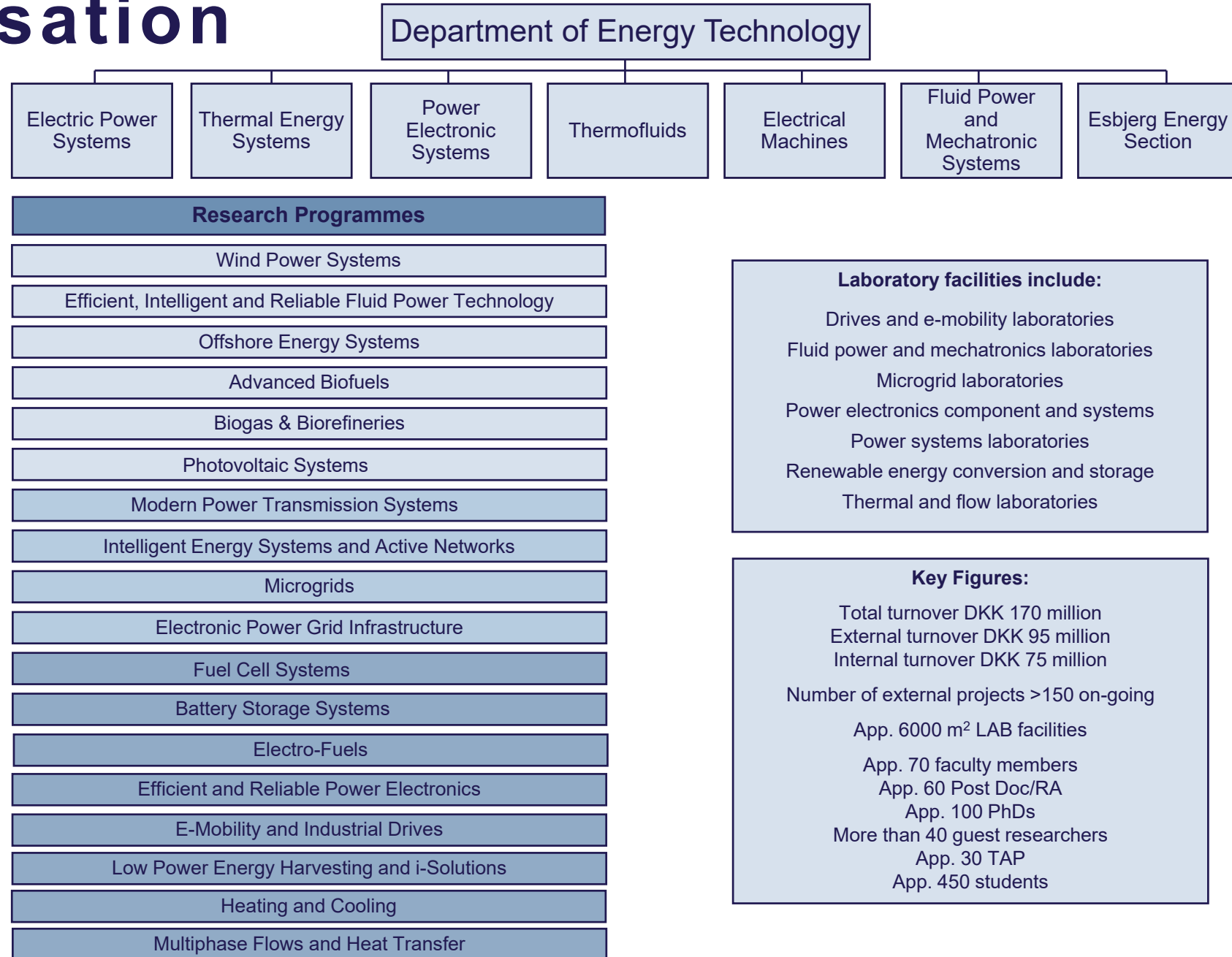
# Energy Technology

Keywords:

- Energy Production
- Energy Distribution
- Energy Consumption
- Energy Control



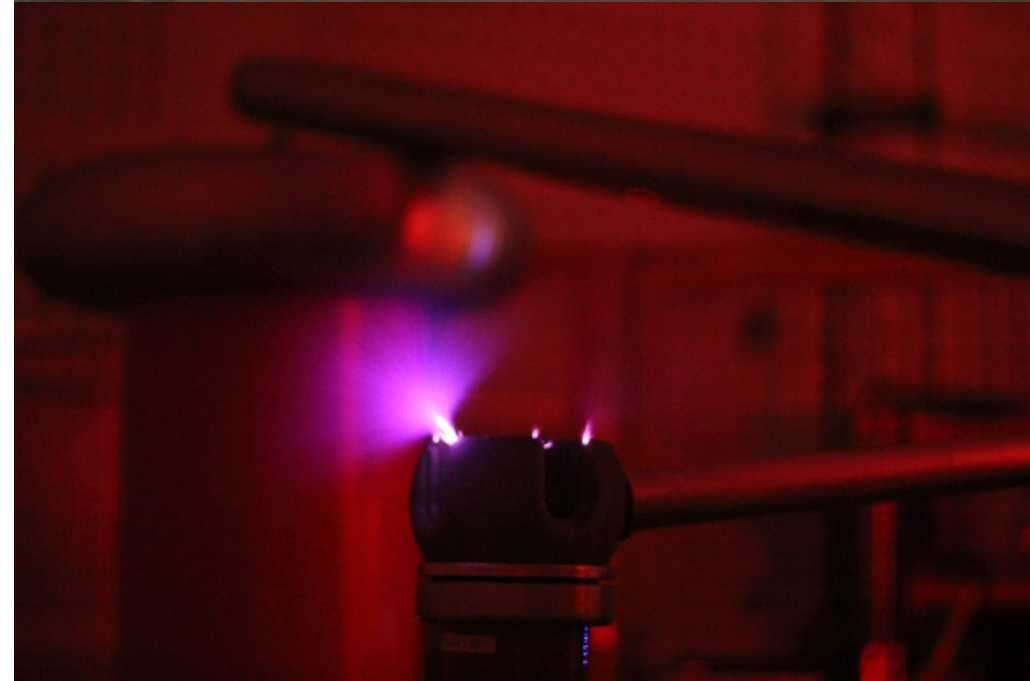
# Organisation

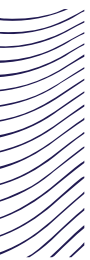


# Electric Power Systems

## Key competences

- Modern OHL technologies
- Electromagnetic transients
- Underground cables in the transmission system
- Power quality and harmonic stability
- Power system stability and voltage control
- Network planning methods
- Power system protection
- HV/MVDC networks and converters
- Simulation models in time- and frequency-domain
- High voltage engineering
- Insulation coordination studies
- Smart grids and distributed generation
- Hierarchical control structures for LV/MV-control
- Electrical usage in heat and transport sectors
- Demand response methods
- Control in relation to the electric market





▶ The University

▶ The Department

▶ The Research Group



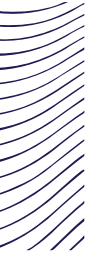


# Modern Power Transmission Systems

## Keywords

- HVAC cable technology
- VSC-HVDC multiterminal transmission
- Composite HV (400 kV) OHL towers
- Modern power system protection schemes (AC and DC)
- Electromagnetic transient simulations and insulation coordination
- Harmonic generation, flow, mitigation and stability in power systems
- Power system stability and wide-area monitoring in networks with large share of renewables and/or HVDC
- High voltage and material characterization
- Railway electrification and voltage unbalance
- Overhead line corona audible noise
- Dynamic line rating







# Modern Power Transmission Systems

## In Brief

- **Work with several topics related with electrical power transmission**
  - Cables, Multiterminal HVDC, High Voltage, Innovative designs, Harmonics, Power System Protection, Distribution Grids, ...
- **Experience working on projects from an industry perspective**
  - Energinet, Ørsted, Bystrup, DEIF, Banedanmark, Nord Energi, InoPower, ...
- **Strong participation in CIGRE activities**
  - Currently in three WG, plus representatives in two SCs and the chairman of the Danish National Committee
- **Well equipped HV and MV laboratories**
  - Both with state-of-the-art equipment, plus equipment for field measurements



*No problems getting hands dirty*



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# Modern Power Transmission Systems

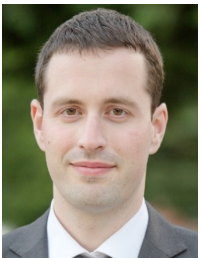
## The Team

- **Claus Leth Bak** (*Professor*)



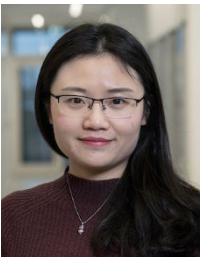
- Main expertise: Corona Phenomena on OHL, Composite Transmission Towers, Power System Modeling and Transient Simulations, Cable transmission, Power System Harmonics, Power System Protection and HVDC-VSC : 2 books and 340 journals/conferences
- 6 years of practical power system engineering experience from I/S Nordjyllandsværket. 20 years wide educational and research experience in power systems and high voltage engineering
- Head of section of electric power systems and high voltage and of Energy Technology PhD program, Chairman of CIGRE Danish NC

- **Filipe Faria da Silva** (*Associate Professor*)



- Main expertise: Insulation coordination and electromagnetic transients; Power cables; Power quality; Power System Protection; HVDC transmission; High Voltage; Power System Stability. 2 books, 35 journal articles and 100 conf. art.
- Leader of research program, coordinator of master program in “Electric Power Systems and High Voltage”. Previously with Energinet
- Convener of a CIGRE WG on TOVs, member of other 2 in the area of insulation coordination and C4 representative

- **Qian Wang** (*Assistant Professor*)



- Main expertise: Electrical design of composite transmission towers; Lightning protection of overhead lines; Insulation material tests; Partial discharge tests. 1 book, more than 10 academic publications.
- Member of the research program







# Modern Power Transmission Systems

## The PhDs (as of December 2019)

- Insulation Evaluation and Design in Power Electronic Components and Systems (Changjiang Zheng)
- Filling Material Investigation of Composite Cross-arms and Grounding Design of a Composite Transmission Tower for 400 kV Overhead Lines (Kai Yin)
- Transient Lightning Impulse Performance Analysis of a Fully Composite Pylon with an External-grounding Down-lead (Hanchi Zhang)
- Measurement of the Transient Impedance of the Grounding System (Vertical Electrode) Buried in the Multi-Layer Stratified Soil Using Small-Scale Setup (Mohammad Ghomi)
- Coordinated control strategy of distributed energy resources in distribution networks (Zhengfa Zhang)
- Ensuring Grid Stability and Supply Reliability in a 100% Renewable Electricity Sector in the Faroe Islands (Helma Maria Trondheim)
- Advanced Protection Technologies of a Cable Dominated Network with large Scale Power Electronics (Kaiqi Ma)
- Protection of Multi-Terminal VSC-HVDC Transmission Lines (Mani Ashouri)

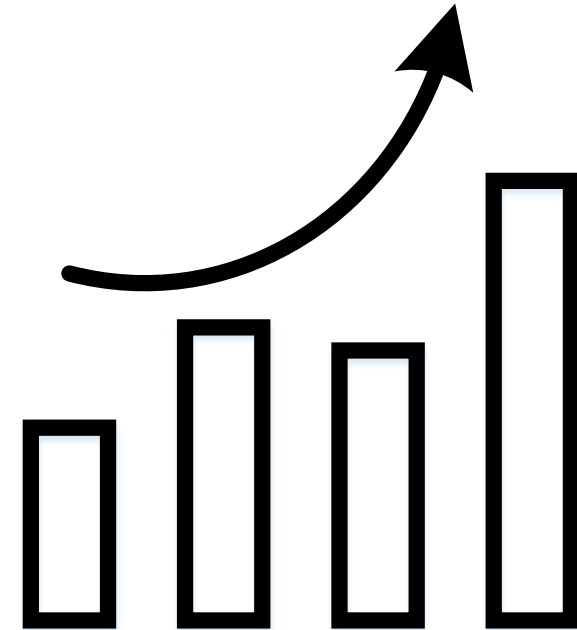




# Modern Power Transmission Systems

## Some numbers from the last 10 years

- Approximately 330 publications:
  - 2 Books
  - ~100 journal articles
  - ~230 conference articles
- 20 PhD students graduated and 8 currently pursuing the degree
- 7 large-scale research projects with industrial partners
- Participation in 6 CIGRE Working Groups





# Previous/current projects: PoPyFu

## Innovative design

Smaller, lighter and more visually appealing

## Studies from scratch are required to assure viability

Material selection, lightning protection and numerous HV issues

**We continue working on new solutions to better improve the concept**



# Previous/current projects: Danpac

## Research how to install HV cables in Denmark

1<sup>st</sup> country in the world undergrounding large parts of the transmission network

### Large range of topics

High frequency modelling, fault location, guidelines for planning and insulation coordination, ...

Little experience worldwide with many of the issues. We have it





# Previous/current projects: COBRACable

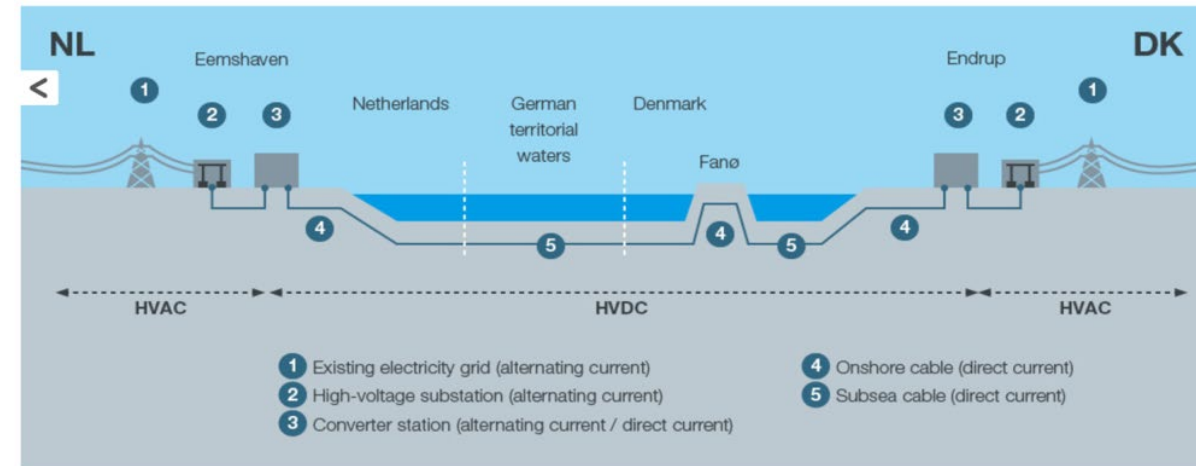
## Solution for incremental HVDC-VSC multiterminal

A tool able to interface converters from different vendors installed at different points in time

## Verified for benchmark and black-box models

Won CIGRE Thesis Award

Multiterminal projects used to require a fix layout.  
Now, there is a plug-and-play tool for a natural grid development



# Previous/current projects: Reliability

## Optimised emergency load-shedding

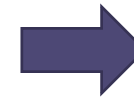
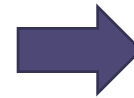
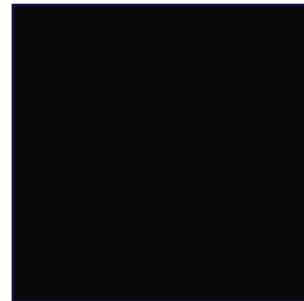
Decrease disconnected load

## Protection solutions for new configurations

Multiterminal HVDC, Power Swings, Penetration of renewable energy sources, Ships

## Use of new measurement tools

Data handling and voltage control



Avoid the “dark”

When it happens, to recover as fast as possible



# Previous/current projects: Grid integration of renewable energy

## Offshore energy

Handling of harmonics and connection issues

## Island Operation

Faroe Islands with 100% green electricity

## Use of generation at distribution grids

Provision of ancillary services to the transmission grid



**The goals for renewable energy integration raise new technical challenges. We try proposing answers**



# Previous/current projects: Harmonics

## Minimise their generation

Previous project with the power electronics

## Study of their propagation

The undergrounding of the grid and/or the use of long lines creates problems not seen before

**This is a topic that we find very important for the future and where we are focusing increasing resources and attention**







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