Modern Power Transmission Systems

Research Program overview & activities (end 2019)
AAU Facts

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

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
AAU organisational chart

UNIVERSITY BOARD

Per Michael Johansen
Rector

Antonino Castrone
University Director

Inger Askehave
Pro-Rector

AAU Shared Services

The Faculty of Social Sciences
- Rasmus Antoft
  Dean
  - Sociology and Social Work
  - Culture and Global Studies
  - Learning and Philosophy
  - Business and Management
  - Department of Political Science
  - Department of Law
  - Schools
    - Sociology and Social Work
    - Consciousness and Human Development
    - Culture and Global Studies
    - Political Science
    - Business and Economics
    - Law
    - Business and Social Sciences, AAU Executive
  - Doctoral schools
    - Doctoral School of Social Sciences

The Faculty of Humanities
- Henrik Halikier
  Dean
  - Communication and Psychology
  - Culture and Global Studies
  - Learning and Philosophy
  - Departments
    - Media and Communication
    - Social Sciences

The Faculty of Medicine
- Lars Hvilsted Rasmussen
  Dean
  - Health Science and Technology
  - Clinical Medicine
  - Departments
    - Medical Science
    - Health Science

Technical Faculty of IT and Design
- Henrik Pedersen
  Dean
  - Computer Science
  - Engineering and Science
  - Departments
    - Computer Science
    - Engineering and Science

The Faculty of Engineering and Science
- Mogens Ryskov Poulsen
  Dean
  - Civil Engineering
  - Energy Technology
  - Mathematical Sciences
  - Chemistry and Innovation
  - Materials and Production
  - Danish Building Research Institute
  - Departments
    - Engineering and Science
    - Civil Engineering

AAU Innovation

Dorte Stigard
Innovation Director

* cross-faculty department or school
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.
DANISH UNIVERSITIES ARE LEADING IN THE FIELD OF ENGINEERING

<table>
<thead>
<tr>
<th>IN EUROPE:</th>
<th>GLOBALLY:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. AAU - Aalborg University (Denmark)</td>
<td>1. Tsinghua University (China)</td>
</tr>
<tr>
<td>2. Imperial College London (United Kingdom)</td>
<td>2. National University of Singapore (Singapore)</td>
</tr>
<tr>
<td>3. Swiss Federal Institute of Technology Zurich (Switzerland)</td>
<td>3. MIT - Massachusetts Institute of Technology (USA)</td>
</tr>
<tr>
<td>4. École Polytechnique Federale of Lausanne (Switzerland)</td>
<td></td>
</tr>
<tr>
<td>5. Delft University of Technology (Netherlands)</td>
<td>8. AAU - Aalborg University (Denmark)</td>
</tr>
<tr>
<td>6. DTU - Technical University of Denmark (Denmark)</td>
<td>24. DTU - Technical University of Denmark (Denmark)</td>
</tr>
</tbody>
</table>

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

The Department

The Research Group
Energy Technology

Keywords:
Energy Production
Energy Distribution
Energy Consumption
Energy Control
Research Programmes

- Wind Power Systems
- Efficient, Intelligent and Reliable Fluid Power Technology
- Offshore Energy Systems
- Advanced Biofuels
- Biogas & Biorefineries
- Photovoltaic Systems
- Modern Power Transmission Systems
- Intelligent Energy Systems and Active Networks
- Microgrids
- Electronic Power Grid Infrastructure
- Fuel Cell Systems
- Battery Storage Systems
- Electro-Fuels
- Efficient and Reliable Power Electronics
- E-Mobility and Industrial Drives
- Low Power Energy Harvesting and i-Solutions
- Heating and Cooling
- Multiphase Flows and Heat Transfer

Laboratory facilities include:
- Drives and e-mobility laboratories
- Fluid power and mechatronics laboratories
- Microgrid laboratories
- Power electronics component and systems
- Power systems laboratories
- Renewable energy conversion and storage
- Thermal and flow laboratories

Key Figures:
- Total turnover DKK 170 million
- External turnover DKK 95 million
- Internal turnover DKK 75 million
- Number of external projects >150 on-going
- App. 6000 m² LAB facilities
- App. 70 faculty members
- App. 60 Post Doc/RA
- App. 100 PhDs
- More than 40 guest researchers
- App. 30 TAP
- App. 450 students
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
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

www.power-systems.et.aau.dk
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
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

www.power-systems.et.aau.dk
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\textsuperscript{st} 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

www.power-systems.et.aau.dk
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

www.power-systems.et.aau.dk
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

www.power-systems.et.aau.dk
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