TU Dortmund University

Faculty of
Electrical Engineering and Information Technology

Module Book

Master Program

Sustainable Energy Systems

Aktualisierte Version
gemäß Beschluss des Fakultätsrates vom
10.04.2024

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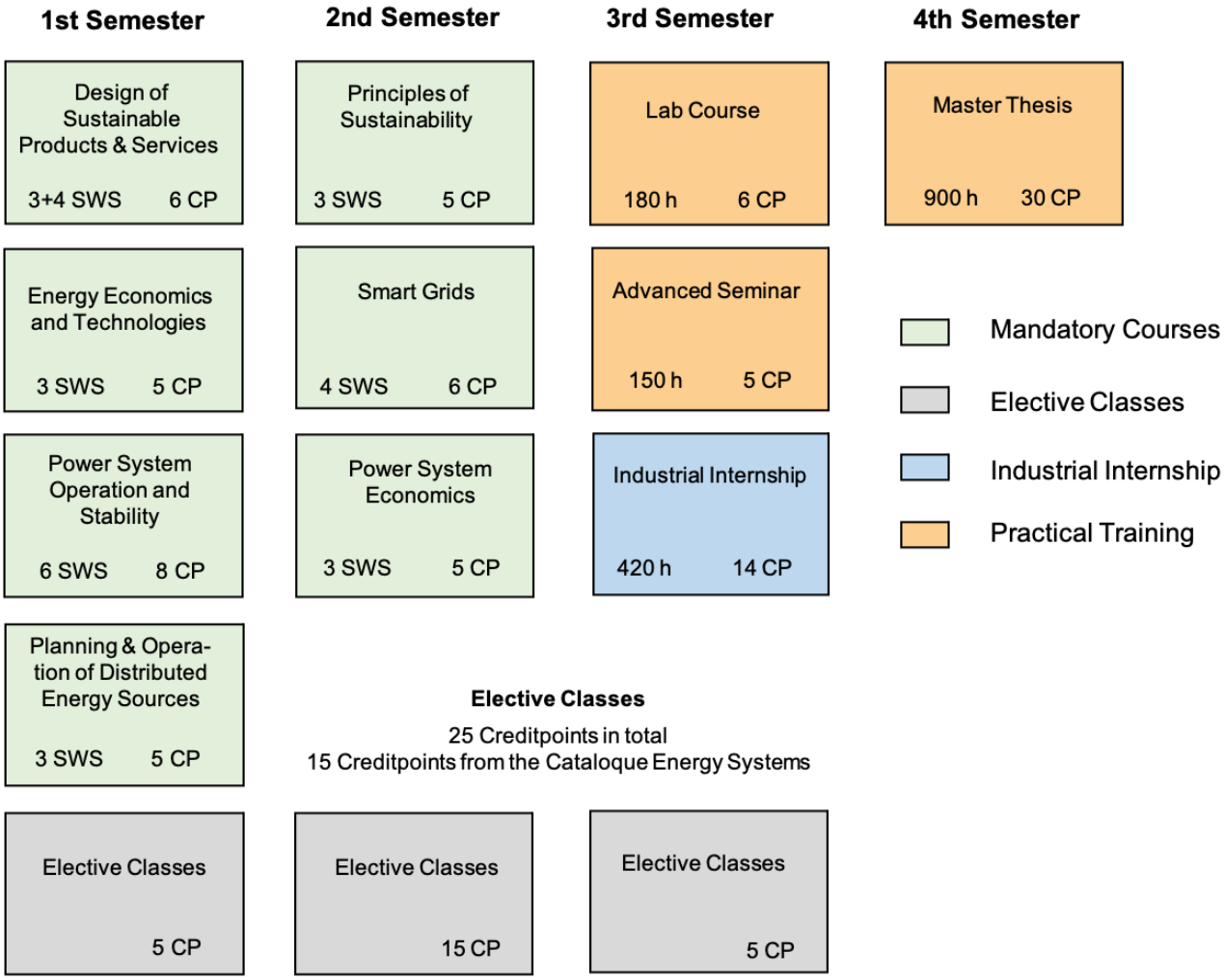
Structure of the Study Program



Aim of the study program and purpose of the examinations

Upon successful completion of the Master's degree course in Sustainable Energy Systems, a further professional qualification is acquired. The Master's degree program builds upon the Bachelor's degree program and requires students to have the qualifications acquired in a relevant Bachelor's degree program. The Master's degree program is research-oriented and serves to deepen both advanced technical and methodological-analytical skills. Students acquire knowledge about the future design of the electrical energy system in the areas of sustainability and digitalization for smart grids and markets. In the application areas, graduates have comprehensive knowledge that corresponds to the current state of the art and are familiar with current problems in energy technology and energy system technology in these areas.

Graduates are able to solve current problems in the areas of application independently (Master's thesis) and in a team (industrial placement) using scientific methods. They have gained an insight into an industrial, engineering-related activity through the industrial internship and, in combination with other training elements, have the skills to quickly integrate into an industrial company in the energy sector. The individually specialized knowledge in one of the focus areas enhances students' abilities to develop new concepts within their discipline and implement them, for example, in a Master's thesis linked to a current research topic. Furthermore, graduates are able to process and present scientific literature in such a way that their peers understand the essential concepts and ideas of these works without having read the papers themselves.

The course covers the areas of design, modelling, control and operation of electrical energy systems, taking sustainability perspectives into account. The course also prepares students for decentralized renewable generation, sector coupling with all energy sectors and the associated energy market designs. Graduates will be able to work in these areas of application without a long period of technical training. In addition, they should be able to develop a fundamental understanding of the possibilities for shaping society as well as the social, ethical, economic, political and technical requirements for a sustainable design of energy generation, use and supply in order to derive and implement responsible action in the technical field.

Students should also apply their ability to think and discuss critically in their later participation in social life. Social commitment, responsible behavior and personal development are included as cross-cutting topics in the degree program. The resulting intercultural skills contribute to students' personal development.

The examinations in the Master's degree program are intended to determine whether the candidate is able to independently analyze technical problems from various areas of electrical and energy systems engineering, break them down into suitable subtasks, solve them using scientific methods and knowledge and thereby achieve an overall solution. In addition, the candidate should show that they can develop new scientific methods under supervision.

The in-depth specialist knowledge, skills and methods of the graduates enable them to work in the broad field of the energy transition as well as to pursue a potential doctorate.

Mandatory Courses

Mandatory Courses

In the 1st and 2nd semesters, a total of 40 credit points in 7 modules must be successfully completed in the compulsory area.

Module M-1: Design of Sustainable Products & Services (DSPS) **SES-101**

Turnus	**Duration**	**Study section**	**CP**	**Attendance rate**	**Self-study**
Annually at WS	1 semester	1st semester	6	75 h	105 h

1 Module structure

No.	Element / Course	LSF no.	Type	LP	SWS
1	Design of Sustainable Products & Serv. Lecture	08 0035	V	3	2
2	Design of Sustainable Products & Serv. Exercise	08 0036	Ü	1	1
3	Design of Sustainable Products & Serv. Practical Training	08 0037	P	2	4

2 Course language:
English

3 Teaching content of elements 1 and 2

1. Design processes for products and services taking into account sustainability criteria
2. Cost accounting for production and operation of products and services
3. Calculation and Optimizing of CO2 footprints of products and services
4. Profitability evaluations (net present value calculation, investment decisions)
5. Sustainability as part of the marketing of products (incl. product life cycle, pricing)
6. Organization of companies and projects
7. Business start-up as an option for implementing sustainable product ideas

Teaching content of element 3

- Computer-based business simulation as an integrated practical course
- Creation of a business plan for a self-selected, innovative and sustainable product or service offering

Literature

Walker, Julia, Alma Pekmezovic, and Gordon Walker. Sustainable development goals: harnessing business to achieve the SDGs through finance, technology and law reform. John Wiley & Sons, 2019.
Kotler, P., Burton, S., Deans, K., Brown, L. & Armstrong, G., 2015. Marketing. Pearson Higher Education.

4 Competencies

After completion of the module examination, the students understand the essential business and sustainability aspects of the realization of electrotechnical systems. They will be able to apply suitable methods to take these aspects into account, e.g. to control the sustainable as well as economic use of resources, to evaluate product realization variants and to estimate market potentials.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of realization of electrotechnical systems, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy and sustainability.

5 Exams

Module exam: Written exam (120 minutes)
Course Credits:

- In Element 2, 50% of the total points earned are through lecture hall exercises.
- The business plan (elements 2 and 3) must be successfully prepared and presented.
- Successful participation and final presentation of the business simulation in Element 3.

The coursework is a prerequisite for taking the module exam.

6 Forms of examination and performance

☒ Module Exam ☐ Partial achievements

7 Participation requirements

None

8 Module type and usability of the module

Mandatory module in the Master's degree program Sustainable Energy Systems.

9	**Module Supervisor**	**Faculty in charge**
	Prof. Dr.-Ing. Christian Wietfeld	Faculty of Electrical Engineering and Information Technology

<table>
<tr><th colspan="7">Module M-2: Energy Economics and Technologies SES-102</th></tr>
<tr><td colspan="2">Turnus
Annually in WS</td><td>Duration
1 Semester</td><td>Study section
1st. semester</td><td>LP
5</td><td>Attendance rate
35 h</td><td>Self-study
115 h</td></tr>
<tr><td>1</td><td colspan="6">Module structure
<table>
<tr><th>Nr.</th><th>Element / Course</th><th>LSF no.</th><th>Typ</th><th>SWS</th></tr>
<tr><td>1</td><td>Energy Economics and Technologies Lecture</td><td>08 xxxx</td><td>V</td><td>2</td></tr>
<tr><td>2</td><td>Energy Economics and Technologies Presentations</td><td>08 xxxx</td><td>Ü</td><td>1</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="6">Course language
English</td></tr>
<tr><td>3</td><td colspan="6">Teaching content
The course focuses on the technologies and economics of energy transitions and the role of public policy in shaping such processes. The content of the course is inherently interdisciplinary, focusing on the technological, economic, social, and environmental challenges related to energy transitions. The students become familiar with the concepts and tools of energy economics and policy analysis. It covers a diverse set of technologies, policy instruments and strategies to support energy transitions and discusses their effectiveness, efficiency and equitability.

Literature
K. Blok: Introduction to Energy Analysis
D. Martinez et. al: Energy Efficiency</td></tr>
<tr><td>4</td><td colspan="6">Competencies
After successfully completing the course, students are familiar with technologies, policy strategies and instruments driving the deployment of sustainable energy solutions. Furthermore, students are able to estimate the economic and social impacts of such policies.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of energy economics and technologies, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy and sustainability.</td></tr>
<tr><td>5</td><td colspan="6">Exams
Module exam:
• Written exam.</td></tr>
<tr><td>6</td><td colspan="6">Forms of examination and performance
☒ Module Exam ☐ Partial achievements</td></tr>
<tr><td>7</td><td colspan="6">Participation requirements
None</td></tr>
<tr><td>8</td><td colspan="6">Module type and usability of the module
Mandatory module in the Master's degree program Sustainable Energy Systems.</td></tr>
<tr><td>9</td><td colspan="3">Module Supervisor
Prof. Stefan Palzer, PhD
Lecturer
Dr. Sibylle Braungardt</td><td colspan="3">Faculty in charge
Faculty of Electrical Engineering and Information Technology</td></tr>
</table>

<table>
<tr><td colspan="7">Modul M-3: Power System Operation and Stability SES-103</td></tr>
<tr><td colspan="2">Turnus
Annually at WS</td><td>Duration
1 Semester</td><td>Study section
1st semester</td><td>LP
8</td><td>Attendance rate
70 h</td><td>Self-study
170 h</td></tr>
<tr><td>1</td><td colspan="6">Module structure
<table>
<tr><th>Nr.</th><th>Element / Course</th><th>LSF no.</th><th>Typ</th><th>SWS</th></tr>
<tr><td>1</td><td>Power System Operation and Stability Lecture</td><td>08 0146</td><td>V</td><td>4</td></tr>
<tr><td>2</td><td>Power System Operation and Stability Exercise</td><td>08 0147</td><td>Ü</td><td>2</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="6">Course language: English</td></tr>
<tr><td>3</td><td colspan="6">Teaching content of elements 1 and 2

The course is structured into two main sections:
1. Power System Supervision, Operation and Protection
1.1. Introduction into electrical power systems and its operational tasks
1.2 System architecture of power system control centers
1.3 Algorithms for power system calculation, supervision and operation
1.4 Substation automation and protection architecture
1.5 Power system protection functions and algorithms for short circuit and fault calculation
1.. Future trends in control centres

2. Power System Stability, Dynamics and Control
2.1 Stability in electrical power systems
2.2 Dynamic power system modelling and simulation
2.3 Small signal and transient rotor angle stability
2.4 Frequency stability
2.5 Voltage stability and voltage control
2.6 Measures to improve stability

Literature
Power System Stability and Control by Kundur
Power System Analysis and Design by Overbye, Glover, Sarma
Power System Operations by Conejo, Baringo</td></tr>
<tr><td>4</td><td colspan="6">Competencies
The transformation of the electrical energy system towards a massive integration of renewable energy resources and sector coupling requires a deep understanding of system operation and stability aspects to guarantee security and reliability.
After successful completion of the module, the students understand the architectural structure of power system supervision, control and protection systems as well as their algorithms for handling the operating conditions of electrical power grids from a security and economic perspective. The students are able to analyse the interaction of the supervision, control and protection components for the future transforming energy system.
Furthermore, they have knowledge about all kinds of power system stability necessary for planning and operation under consideration of renewable energy and sector coupling. They are able to choose the appropriate models for stability assessment. Based on these, the dynamic behaviour and stability can be calculated and analysed.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of power system operation and stability, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy and sustainability.</td></tr>
<tr><td>5</td><td colspan="6">Exams
Module examination: oral examination (max. 40 minutes) or written examination (max. 180 minutes).*

*The exact examination modalities will be announced by the 2nd course at the latest.</td></tr>
<tr><td>6</td><td colspan="6">Prüfungsformen und -leistungen
☒ Module Exam ☐ Partial achievements</td></tr>
</table>

7	**Participation requirements** None	
8	**Module type and usability of the module** Mandatory module in the Master's degree program Sustainable Energy Systems.	
9	**Module Supervisor** Prof. Dr.-Ing. Christian Rehtanz	**Faculty in charge** Faculty of Electrical Engineering and Information Technology

<table>
<tr><th colspan="7">Modul M-4: Planning & Operation of Distributed Energy Sources SES-104</th></tr>
<tr><td colspan="2">Turnus
Annually at WS</td><td>Duration
1 Semester</td><td>Study section
1st semester</td><td>LP
5</td><td>Attendance rate
35 h</td><td>Self-study
115 h</td></tr>
<tr><td>1</td><td colspan="6">Module structure
<table>
<tr><th>Nr.</th><th>Element / Course</th><th>LSF no.</th><th>Typ</th><th>SWS</th></tr>
<tr><td>1</td><td>Planning & Operation of Distributed Energy Sources</td><td>08 XXXX</td><td>V</td><td>2</td></tr>
<tr><td>2</td><td>Planning & Operation of Distributed Energy Sources</td><td>08 XXXX</td><td>Ü</td><td>1</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="6">Course language
English</td></tr>
<tr><td>3</td><td colspan="6">Teaching content
Electrical energy systems are undergoing a massive transformation towards CO_2 -neutral technologies for electricity generation. Large-scale power plants are increasingly being replaced by distributed energy conversion plants. This results in new requirements for the operation of distributed resp. decentral supplied electrical energy systems and grids. Within this lecture, different technologies for energy conversion are introduced. In particular, the requirements for system integration, design, grid connection and operation are examined in detail. The lecture is structured into the following topics:
1. Introduction to the implementation of distributed energy systems
2. Technologies of distributed energy conversion and storage
3. Grid connection guidelines and protection of distributed energy conversion systems in low and medium voltage grids
4. Power grid influences and control strategies of converter-based energy conversion
5. Design and evaluation of the economic efficiency of distributed energy conversion systems

Literature
Renewable energy conversion systems - 1st Edition, Muhammad Kamran & Muhammad Fazal, ISBN: 9780128235980</td></tr>
<tr><td>4</td><td colspan="6">Competencies
After successful completion of the module, the students know the process and the effects of the change from a centralised to a decentralised energy supply. They can classify the associated effects and know a selection of (technical control) measures to increase the integration capability of decentralised energy conversion plants in the electrical distribution grids. Furthermore, they are familiar with the different plant technologies for decentralised and regenerative electrical energy conversion. They know the different connection options and their protection concepts according to the common application rules. They are able to plan and operate decentralised energy conversion plants safely, taking into account the economic and technical boundary conditions.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of distributed energy sources, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy and sustainability.</td></tr>
<tr><td>5</td><td colspan="6">Exams
Module exam: oral exam (max. 30 minutes) or written exam (max. 90 minutes) *

*The exact examination modalities will be announced by the 2nd course at the latest.</td></tr>
<tr><td>6</td><td colspan="6">Forms of examination and performance
☒ Module Exam ☐ Partial achievements</td></tr>
<tr><td>7</td><td colspan="6">Participation requirements
Recommended prerequisites: Knowledge of the fundamentals of power engineering and electrical power systems.</td></tr>
<tr><td>8</td><td colspan="6">Module type and usability of the module
Mandatory module in the Master's degree program Sustainable Energy Systems.</td></tr>
</table>

9	**Module Supervisor** Prof. Dr.-Ing. Christian Rehtanz	**Faculty in charge** Faculty of Electrical Engineering and Information Technology

<table>
<tr><td colspan="7">Modul M-5: Principles of Sustainability SES-105</td></tr>
<tr><td colspan="2">Rota
Anually at SoSe</td><td>Duration
1 Semester</td><td>Semester
2nd Semester</td><td>Credits
5</td><td>Attendance
35 h</td><td>Self-study
115 h</td></tr>
<tr><td>1</td><td colspan="6">Module structure
<table>
<tr><th>Nr.</th><th>Courses</th><th>LSF no.</th><th>Type</th><th>SWS</th></tr>
<tr><td>1</td><td>Principles of Sustainability</td><td>08 XXXX</td><td>V</td><td>2</td></tr>
<tr><td>2</td><td>Principles of Sustainability</td><td>08 XXXX</td><td>Ü</td><td>1</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="6">Language
English</td></tr>
<tr><td>3</td><td colspan="6">Content
1. What is Sustainability?
2. Legal framework
3. Reporting und Monitoring
4. Our CO2 footprint
5. Circular Economy in the context of energy supply
6. Climate neutral energy supply and demand
7. Sustainable solutions for energy systems (2 lectures)
8. Social Responsibility
9. The Year 2040

Literature
tbd</td></tr>
<tr><td>4</td><td colspan="6">Competencies
After the successful completion, students have the necessary solid knowledge on principles of sustainability. They can put sustainable approaches and solutions into the context of the current legal framework and develop appropriate reporting and monitoring methods. The handling of the different levels of sustainability and their necessary interaction is conveyed based on energy systems. The students can derive the impact of new technology and processes on the path of sustainability.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of sustainability, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy.</td></tr>
<tr><td>5</td><td colspan="6">Examination
Module exam: oral exam (max. 40 minutes) or written exam (max. 90 minutes) *
Examination prerequisites: tbd

* The exact examination modalities will be announced at the latest for the 2nd event.</td></tr>
<tr><td>6</td><td colspan="6">Type and Performance of Examination
☒ Module Exam ☐ Accumulated grade</td></tr>
<tr><td>7</td><td colspan="6">Module prerequisites
Recommended preconditions: Knowledge about principles of energy technology</td></tr>
<tr><td>8</td><td colspan="6">Module type and usability of the module
Mandatory module in the Master's degree program Sustainable Energy Systems.</td></tr>
<tr><td>9</td><td colspan="3">Module Supervisor
Hon.Prof. Dr.-Ing. Lars Jendernalik</td><td colspan="3">Faculty in charge
Faculty of Electrical Engineering and Information Technology</td></tr>
</table>

Modul M-6: Smart Grids					SES-106
Turnus Annually at SS	**Duration** 1 Semester	**Study section** 2nd Semester	**LP** 6	**Attendance rate** 55 h	**Self-study** 125 h

1 Module structure

Nr.	Element / Course	LSF no.	Typ	SWS
1	Smart Grids Lecture	08 0102	V	3
2	Smart Grids Practical works	08 0103	P	1

2 Course language
Englisch

3 Teaching content
This course will handle the following aspects of the changing electrical energy network:

1. Energy transition towards sustainability
2. New distribution grid users (renewable energy sources, loads and energy storage)
3. Electro-mobility
4. Conventional distribution grids and their transformation for massive renewable integration
5. State estimation
6. Congestion management (Voltage CM and Thermal CM)
7. Protection and control functions
8. Timeseries based planning of renewable dominated distribution grids
9. Grid automation and future trends

4 Competencies
Renewable energy resources are primarily integrated on the distribution grid level. Therefore, competencies of understanding the integration of renewable energy resources into the distribution grids are key for transforming the energy system towards sustainability.
The students successfully finishing the course should be able to
• understand the challenges in todays and future sustainable electrical energy distribution grids
• comprehend the multiple areas of research done in the distribution grids
• develop new solution approaches for energy system transformation towards renewable energy integration based on their acquired knowledge through lectures and practical works
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of smart grids, this includes, for example, raising awareness of socially relevant topics such as age and technology or data security and digital participation.

5 Exams
Module Exam: oral exam (max. 30 minutes) or written exam (max. 120 minutes) *
Prerequesites: Active participation in practical works (laboratory tasks, presentations, etc.,) is also a prerequisite to participate in the examination

* The responsible lecturer will announce the mode of the examination two weeks after the start of the lecture at the very latest.

6 Forms of examination and performance
☒ Module Exam ☐ Partial achievements

7 Participation requirements
Basic knowledge in Electrical Energy Engineering

8 Module type and usability of the module
Mandatory module in the Master's degree program Sustainable Energy Systems.

9 Module Supervisor	**Faculty in charge**
Dr.-Ing. Ulf Häger	Faculty of Electrical Engineering and Information Technology

Modul M-7: Power System Economics					ETIT-224
Turnus Annually at SS	**Duration** 1 Semester	**Study section** 2nd Semester	**LP** 5	**Attendance rate** 35 h	**Self-study** 115 h

1 Module structure

Nr.	Element / Course	LSF no.	Typ	SWS
1	Power System Economics Lecture	08 0227	V	2
2	Power System Economics Exercise	08 0228	Ü	1

2 Course language
Deutsch

3 Teaching content
1. Organization of the electricity market and regulatory framework for sustainable energy systems
2. Regulation in electrical power and energy systems
3. Optimization methods in the electricity industry
4. Unit Commitment
5. Grid charges and transmission rights
6. Modeling and simulation of electricity markets and grids with massive integration of renewable energy sources
7. Cross-border electrical energy trading capacities
8. Network congestion management and redispatch optimisation
9.Portfolio optimization and risk management
10. Investment in generation and grid capacity

Literature
D. Kirschen: Fundamentals of Power System Economics, Wiley

4 Competencies
After successful completion, students have a sound knowledge of market mechanisms and management strategies in grid-based energy supply. They are able to discuss the technical constraints from the power grids to primarily renewable based energy supply in economic and business contexts. They are able to apply their knowledge in power system economics to further developments in the technical, market and regulatory context towards sustainable, sector-coupled and renewable based energy systems. In addition to the electricity industry in general, the special focus of this lecture is on the electrical network industry.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of power system economics, this includes, for example, raising awareness of socially relevant topics such as age and technology or data security and digital participation.

5 Exams
Module Exam: oral exam (max. 40 minutes) or written exam (max. 180 minutes) *

*The exact examination modalities will be announced by the 2nd course at the latest.

6 Forms of examination and performance
☒ Module Exam ☐ Partial achievements

7 Participation requirements
Recommended prerequisites: Knowledge of the basics of power engineering

8 Module type and usability of the module
Mandatory module in the Master's degree program Sustainable Energy Systems.

9 Module Supervisor	**Faculty in charge**
Prof. Dr.-Ing. Christian Rehtanz	Faculty of Electrical Engineering and Information Technology

Elective Classes – Cataloque Energy Systems

Elective Classes

A total of 25 credit points must be successfully acquired in the compulsory elective modules (according to the study plan for semesters 1, 2 and 3).
15 of the 25 credit points are to be selected from the Energy Systems catalogue.
10 credit points are freely selectable.

<table>
<tr><th colspan="7">Modul 2-35: Selected Chapters in High Voltage Technology ETIT-288</th></tr>
<tr><td colspan="2">Turnus
Annually at SS</td><td>Duration
1 Semester</td><td>Study section
2nd Semester</td><td>LP
5</td><td>Attendance rate
35 h</td><td>Self-study
115 h</td></tr>
<tr><td>1</td><td colspan="6">Module structure
<table>
<tr><th>Nr.</th><th>Element / Course</th><th>LSF no.</th><th>Typ</th><th>SWS</th></tr>
<tr><td>1</td><td>Selected Chapters in High Voltage Technology (lecture)</td><td>08 0203</td><td>V</td><td>2</td></tr>
<tr><td>2</td><td>Selected Chapters in High Voltage Technology (tutorial)</td><td>08 0204</td><td>Ü</td><td>1</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="6">Course language
Deutsch</td></tr>
<tr><td>3</td><td colspan="6">Teaching content
1. requirements for high-voltage equipment
2. technology, structure and design
3. insulation systems for DC
4. diagnostic methods and technology trends
5. examples and applications from practice
Literature
Kuffel: High Voltage Engineering Fundamentals,
Küchler: High Voltage Engineering - Fundamentals - Technology - Applications</td></tr>
<tr><td>4</td><td colspan="6">Competencies:
Students acquire detailed knowledge of selected operating equipment of power transmission systems. They are familiar with the constructive structure and electrical design and know the technological boundaries which apply for high-voltage devices. The participants are familiar with procedures and measurement methods for quality assurance reasons and diagnostics on high-voltage devices. Examples and applications deepen the knowledge and establish the reference to the operational practice.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of high-voltage technology, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy and sustainability.</td></tr>
<tr><td>5</td><td colspan="6">Exams
Module Exam: oral exam (max. 40 minutes) or written exam (max. 180 minutes) *

*The exact examination modalities will be announced by the 2nd course at the latest.</td></tr>
<tr><td>6</td><td colspan="6">Forms of examination and performance
☒ Module Exam ☐ Partial achievements</td></tr>
<tr><td>7</td><td colspan="6">Participation requirements
Recommended prerequisites: Sufficient knowledge in energy technology, as can be acquired e.g. through participation in the basic module "Field and Network-Based Modelling".</td></tr>
<tr><td>8</td><td colspan="6">Module type and usability of the module
Elective Class in the Master's degree program Sustainable Energy Systems, Energy Systems Cataloque.</td></tr>
<tr><td>9</td><td colspan="3">Module Supervisor
Prof. Dr.-Ing. Frank Jenau</td><td colspan="3">Faculty in charge
Faculty of Electrical Engineering and Information Technology</td></tr>
</table>

Modul 2-36: Automotive Systems					**ETIT-291**
Turnus Annually at SS	**Duration** 1 Semester	**Study section** 2nd Semester	**LP** 5	**Attendance rate** 35 h	**Self-study** 115 h

1 Module structure

Nr.	Element / Course	LSF no.	Typ	SWS
1	Automotive Systems (lecture)	08 0008	V	2
2	Automotive Systems (tutorial)	08 0009	Ü	1

2 Course language
Englisch

3 Lehrinhalte

1. Vehicle dynamics (tires, longitudinal and lateral dynamics)
2. Actuators in the mechatronic vehicle (steering, braking, and powertrain systems)
3. (Kinematic) vehicle models
4. Sensors measuring vehicle internal quantities (acceleration, yaw rate, steering angle, steering torque, wheel speed, sensor data processing)
5. Vehicle dynamics systems (braking and driving slip control systems)
6. Modern headlight systems and light engineering

Literature:
- R. Rajamani: Vehicle Dynamics and Control (Springer)
- U. Kiencke, L. Nielsen: Automotive Control Systems (Springer)

4 Competencies
The students acquire a profound knowledge of vehicle dynamics systems (dynamics, sensors measuring vehicle dynamics quantities, actuators, models, simulation, control, and optimization). They are able to understand and solve tasks on vehicle dynamics systems with appropriate methods.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of vehicle dynamics systems, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy and sustainability.

5 Exams
Module Exam: oral exam (max. 40 minutes) or written exam (max. 180 minutes) *

*The exact examination modalities will be announced by the 2nd course at the latest.

6 Prüfungsformen und -leistungen
☒ Module Exam ☐ Partial achievements

7 Participation requirements
Recommended prerequisites: Basic knowledge of mechatronics and mechanics.

8 Module type and usability of the module
Elective Class in the Master's degree program Sustainable Energy Systems, *Energy Systems Cataloque*.

9 Module Supervisor	**Faculty in charge**
Prof. Dr.-Ing. Prof. h.c. Dr. h.c. Torsten Bertram	Faculty of Electrical Engineering and Information Technology

Modul 3-28: Machine Learning in Robotics					ETIT-277
Turnus Annually at SS	**Duration** 1 Semester	**Study section** 2nd Semester	**LP** 5	**Attendance rate** 35 h	**Self-study** 115 h

1 Module structure

Nr.	Element / Course	LSF no.	Typ	SWS
1	Machine Learning in Robotics (lecture)	08 0808	V	2
2	Machine Learning in Robotics (tutorial)	08 0809	Ü	1

2 Course language
Englisch

3 Teaching content
1. Fundamentals of Machine Learning
2. Nonlinear Regression
3. Neural Networks
4. Deep Learning
5. Reinforcement Learning

Literature:
Ian Goodfellow, Yoshua Bengio, Aaron Courville, Deep Learning, MIT Press, 2016
Richard Sutton, Andrew G. Barton, Reinforcement Learning an Introduction, 2nd edition, MIT Press, 2018
ausgewählte Veröffentlichungen aus Zeitschriften und Konferenzen

4 Competencies
The students acquire a profound knowledge of theoretical concepts and practical applications of machine learning in robotics. Students are able to solve machine learning tasks for supervised and reinforcment learning with methods and algorithms within Matlab and ROS.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of machine learning in robotics, this includes, for example, raising awareness of socially relevant topics such as age and technology or data security and digital participation.

5 Exams
Module Exam: oral exam (max. 40 minutes) or written exam (max. 180 minutes) *

*The exact examination modalities will be announced by the 2nd course at the latest.

6 Prüfungsformen und -leistungen
☒ Module Exam ☐ Partial achievements

7 Participation requirements
None

8 Module type and usability of the module
Elective Class in the Master's degree program Sustainable Energy Systems, *Energy Systems Cataloque*.

9 Module Supervisor	**Faculty in charge**
apl. Prof. Dr. rer. nat. Frank Hoffmann	Faculty of Electrical Engineering and Information Technology

Modul 2-48: Optimal Power Flow Problems					ETIT-406
Turnus Annually at SS	**Duration** 1 Semester	**Study section** 2nd Semester	**LP** 5	**Attendance rate** 35 h	**Self-study** 115 h

1 Module structure

Nr.	Element / Course	LSF no.	Typ	SWS
1	Optimal Power Flow Problems (lecturer)	08 XXXX	V	2
2	Optimal Power Flow Problems (tutorial)	08 XXXX	Ü	1

2 Course language

Englisch

3 Lehrinhalte

The problem of Optimal Power Flow (OPF) in power systems occurs in various formulations and variants in power engineering. In this context, the lecture offers an introduction to different aspects of OPF problems. The following topics are covered:

- Formulation of the OPF problem in AC
- Convex approximations of the OPF problem
- Stochastic formulations of the AC OPF problem
- Dynamic formulations of the OPF problem for transmission and distribution networks considering storage dynamics
- Distributed formulations of the OPF problem
- Outlook on approaches for the coupling of electric grids and gas grids

The solution will be tested practically with the help of standard software (e.g. Matpower or Pan-dapower, powermodels.jl).

Literature

Frank, Stephen, Ingrida Steponavice, and Steffen Rebennack. "Optimal power flow: a bibliographic survey I." Energy systems 3.3 (2012): 221-258.
Frank, Stephen, Ingrida Steponavice, and Steffen Rebennack. "Optimal power flow: a bibliographic survey II." Energy systems 3.3 (2012): 259-289.
Capitanescu, Florin. "Critical review of recent advances and further developments needed in AC optimal power flow." Electric Power Systems Research 136 (2016): 57-68.
Faulwasser, Timm, Alexander Engelmann, Tillmann Mühlpfordt, and Veit Hagenmeyer. "Optimal power flow: an introduction to predictive, distributed and stochastic control challenges." at-Automatisierungstechnik 66, no. 7 (2018): 573-589.

4 Competencies

After successful participation in the module, the students have basic knowledge of formulating and solving OPF problems. In particular, they are able to recognise the different types of OPF problems, formulate them and solve them with the help of suitable software tools.
Using practical examples, the students have also gained an insight into the diverse application possibilities of the OPF problem in energy technology.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of OPF problems, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy and sustainability.

5 Exams

Partial achievements:

- Written exam (90 minutes) or oral exam (max. 30 minutes)
- Project work accompanying the lecture with written report *

* The overall grade is formed from the arithmetic mean of the partial grades. The exact examination modalities will be announced by the 2nd course at the latest.

6	**Forms of examination and performance** ☐ Module Exam ☒ Partial achievements	
7	**Participation requirements** Recommended prerequisites: Prior knowledge of the fundamentals of electrical power engineering	
8	**Module type and usability of the module** Elective Class in the Master's degree program Sustainable Energy Systems, *Energy Systems Cataloque*.	
9	**Module Supervisor** Prof. Dr.-Ing. Timm Faulwasser	**Faculty in charge** Faculty of Electrical Engineering and Information Technology

<table>
<tr><td colspan="7">Modul 3-33: Electric Drive Systems ETIT-283</td></tr>
<tr><td colspan="2">Turnus
Annually at WS</td><td>Duration
1 Semester</td><td>Study section
3rd Semester</td><td>LP
5</td><td>Attendance rate
35 h</td><td>Self-study
115 h</td></tr>
<tr><td>1</td><td colspan="6">Module structure
<table>
<tr><th>Nr.</th><th>Element / Course</th><th>LSF no.</th><th>Typ</th><th>SWS</th></tr>
<tr><td>1</td><td>Electric Drive Systems (lecture)</td><td>08 0132</td><td>V</td><td>2</td></tr>
<tr><td>2</td><td>Electric Drive Systems (tutorial)</td><td>08 0133</td><td>Ü</td><td>1</td></tr>
<tr><td>3</td><td>Electric Drive Systems (course lab)</td><td>08 0134</td><td>P</td><td></td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="6">Course language
Deutsch</td></tr>
<tr><td>3</td><td colspan="6">Teaching content
1. Structure of electric drive systems
2. Principles and modeling of electrical machines
3. Variable speed operation and position sensing methods.
4. Drive inverters and modulation techniques

Literature
Krause: Analysis of Electric Machinery and Drive Systems, IEEE-Wiley Press</td></tr>
<tr><td>4</td><td colspan="6">Competencies
After successful completion, students will be familiar with the essential properties of the electrical machines used in electric drive systems today and with their application in traction and industry. They are able to mathematically describe and design drive control systems consisting of electrical machines and drive inverters. They successfully apply the common methods for speed control including sensorless operation.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of electric drive systems, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy and sustainability.</td></tr>
<tr><td>5</td><td colspan="6">Exams
Module Exam: oral exam (max. 40 minutes) or written exam (max. 180 minutes) *
Course achievements: Successful completion of the lab course attempt in part 3.

* The exact examination modalities will be announced by the 2nd course at the latest.

The course work is a prerequisite for participation in the Module Exam.</td></tr>
<tr><td>6</td><td colspan="6">Forms of examination and performance
☒ Module Exam ☐ Partial achievements</td></tr>
<tr><td>7</td><td colspan="6">Participation requirements
Recommended prerequisites: Fundamentals of electrical machines.</td></tr>
<tr><td>8</td><td colspan="6">Module type and usability of the module
Elective Class in the Master's degree program Sustainable Energy Systems, Energy Systems Cataloque.</td></tr>
<tr><td>9</td><td colspan="3">Module Supervisor
Prof. Dr.-Ing. Martin Pfost</td><td colspan="3">Faculty in charge
Faculty of Electrical Engineering and Information Technology</td></tr>
</table>

Elective Classes

Elective Classes
A total of 25 credit points must be successfully acquired in the compulsory elective modules (according to the study plan for semesters 1, 2 and 3).
15 of the 25 credit points are to be selected from the Energy Systems catalogue.
10 credit points are freely selectable.

<table>
<tr><td colspan="7">Modul 2-19: Local Networks – Communication and Control ETIT-238</td></tr>
<tr><td colspan="2">Turnus
Annually at SS</td><td>Duration
1 Semester</td><td>Study section
2nd Semester</td><td>LP
5</td><td>Attendance rate
35 h</td><td>Self-study
115 h</td></tr>
<tr><td>1</td><td colspan="6">Module structure
<table>
<tr><th>Nr.</th><th>Element / Course</th><th>LSF no.</th><th>Typ</th><th>SWS</th></tr>
<tr><td>1</td><td>Local Networks - Communication and Control (lecture)</td><td>08 0802</td><td>V</td><td>2</td></tr>
<tr><td>2</td><td>Local Networks - Communication and Control (tutorial)</td><td>08 0803</td><td>Ü</td><td>1</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="6">Course language
Englisch</td></tr>
<tr><td>3</td><td colspan="6">Teaching content
1. basics of networks: technical concepts and applications
2. system examples of wired networks: CAN bus, Ethernet, USB
3. system examples of wireless networks: WLAN, Bluetooth, Zigbee

Literature
Surgeon: Ethernet
Rech: Wireless LANs
Miller, Bisdikian: Bluetooth Revealed</td></tr>
<tr><td>4</td><td colspan="6">Competencies
After successful completion, the students are able to evaluate the different concepts for local networks with regard to their performance, understand existing standards and build systems as well as assess current further developments of the technology.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of local networks, this includes, for example, raising awareness of socially relevant topics such as age and technology or data security and digital participation.</td></tr>
<tr><td>5</td><td colspan="6">Exams
Module Exam: oral exam (max. 40 minutes) or written exam (max. 180 minutes) *

* The exact examination modalities will be announced by the 2nd course at the latest.</td></tr>
<tr><td>6</td><td colspan="6">Forms of examination and performance
☒ Module Exam ☐ Partial achievements</td></tr>
<tr><td>7</td><td colspan="6">Participation requirements
None</td></tr>
<tr><td>8</td><td colspan="6">Module type and usability of the module
Elective Class in the Master's degree program Sustainable Energy Systems.</td></tr>
<tr><td>9</td><td colspan="3">Module Supervisor
Dr.-Ing. W. Endemann</td><td colspan="3">Faculty in charge
Faculty of Electrical Engineering and Information Technology</td></tr>
</table>

Modul 3-20: Mobile Robots					ETIT-269
Turnus Annually at SS	**Duration** 1 Semester	**Study section** 2nd Semester	**LP** 5	**Attendance rate** 50 h	**Self-study** 100 h

1 Module structure

Nr.	Element / Course	LSF no.	Typ	SWS
1	Mobile Robots (lecture)	08 0154	V	2
2	Mobile Robots (tutorial)	08 0155	Ü	2

2 Course language
Englisch

3 Teaching content

1. Robot Operating System (ROS)
2. Robotics System Toolbox Matlab
3. Sensors, actuators and kinematics of mobile robots
4. Homing and trajectory following
5. Obstacle avoidance (Vector Field Histograms)
6. Localisation
7. Path planning (Rapidly Exploring Random Trees, Probabilistic Roadmap)
8. Navigation (Pure Pursuit, ROS Navigation Stack)
9. Online trajectory optimization
10. Mapping and SLAM

Literature
- Siciliano, Khatib: Springer Handbook of Robotics
- ausgewählte Artikel zur mobilen Robotik aus Konferenzen und Zeitschriften

4 Competencies
The students acquire a profound knowledge of fundamental concepts and practical experience on mobile robots. Students are able to solve mobile robotic tasks such as obstacle avoidance, navigation and localization in a self-dependent manner with selected methods and algorithms in ROS/Matlab.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of mobile robots, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy and sustainability.

5 Exams
Module Exam: oral exam (max. 40 minutes) or written exam (max. 180 minutes) *
Study achievements:

- Successful completion of at least 75% of the practical exercises in ROS/Matlab for programming mobile robots.

The course work is a prerequisite for participation in the Module Exam.

* The exact examination modalities will be announced by the 2nd course at the latest.

6 Forms of examination and performance
☒ Module Exam ☐ Partial achievements

7 Participation requirements
None

8 Module type and usability of the module
Elective Class in the Master's degree program Sustainable Energy Systems.

9 Module Supervisor	**Faculty in charge**
apl. Prof. Dr. rer. nat. Frank Hoffmann	Faculty of Electrical Engineering and Information Technology

Modul 2-34: Remote Sensing						ETIT-287
Turnus Annually at SS	**Duration** 1 Semester	**Study section** 2nd Semester	**LP** 5	**Attendance rate** 35 h	**Self-study** 115 h	

1 Module structure

Nr.	Element / Course	LSF no.	Typ	SWS
1	Remote Sensing (lecture)	08 0243	V	2
2	Remote Sensing (tutorial)	08 0244	Ü	1

2 Course language English

3 Lehrinhalte

1. sensor systems for taking aerial and satellite images
2. properties of aerial and satellite images in different spectral ranges
3. correction methods for atmospheric and topographic effects
4. methods for the analysis of image data in remote sensing applications
5. methods for the analysis of spectral data in remote sensing applications
6. orthorectification, georeferencing and coregistration of aerial and satellite imagery
7. classification methods for multi- and hyperspectral imagery data
8. practical application examples from current research

Literature

Schowengerdt, R.A.: Remote Sensing: Models and Methods for Image Processing. 3rd Edition, Academic Press, 2007.

4 Competencies

After successful completion of the module, the students master the essential basics of remote sensing as well as the signal and image processing methods required for this. The students can classify tasks for remote sensing systems from different application areas and solve them independently with independently selected methods.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of remote sensing, this includes, for example, raising awareness of socially relevant topics such as age and technology or data security and digital participation.

5 Exams

Module Exam: oral exam (max. 40 minutes) or written exam (max. 180 minutes)*

* The exact examination modalities will be announced by the 2nd course at the latest.

6 Forms of examination and performance

☒ Module Exam ☐ Partial achievements

7 Participation requirements

Recommended knowledge: Sufficient knowledge in basics of electrical engineering, signal processing, image processing

8 Module type and usability of the module

Elective Class in the Master's degree program Sustainable Energy Systems.

9 Module Supervisor	**Faculty in charge**
Prof. Dr.rer.nat. Christian Wöhler	Faculty of Electrical Engineering and Information Technology

Module 2-49: Mobile Radio Networks 1: Fundamentals and Design Aspects						ETIT-407
Rota Anually at SS	**Duration** 1 Semester	**Semester** 2nd Semester	**Credits** 5	**Presence** 35 h	**Self-Study Load** 115 h	

1 Module Structure

No.	Element / Course	LSF-No.	Type	SWS
1	Mobile Radio Networks 1: Fundamentals and Design Aspects: Lecture	08 0104	V	2
2	Mobile Radio Networks 1: Fundamentals and Design Aspects: Lab Course	08 0105	P	1

2 Language
English

3 Content

1. Market aspects and historical development of mobile communications
2. System aspects (characteristics of propagation, subscriber mobility, resource demand and spectrum allocation, network planning, protocols)
3. TDMA- und CDMA-based cellular networks (2G GSM/GPRS/EDGE, 3G UMTS/HSPA)
4. System architecture of OFDMA-based cellular networks (4G LTE)

The discussion of theoretical content is complemented by practical demonstrations and by case studies on ongoing research and business aspects of mobile radio networks.

Literature (respective latest version)
Walke, B.: Mobile Radio Networks, Wiley
Rappaport, Theodore S. Wireless communications: principles and practice. Prentice Hall.
Dahlmann, E.; Parkvall, S.; Sköld, J.: 4G: LTE/LTE-Advanced for Mobile Broadband, Academic Press

4 Competencies
After successful completion of the module, students understand the system architectures, protocols, dimensioning and operation of mobile radio networks. Students are able to evaluate the possibilities and challenges of using wireless networks in different deployment environments and fields of application, and to make a technically sound selection. In this way, they acquire the competence to attend more advanced courses or to study more advanced topics for themselves.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of mobile radio networks, this includes, for example, raising awareness of socially relevant topics such as age and technology or data security and digital participation.

5 Examination
*Module exam: oral exam (max. 40 minutes) or written exam (max. 180 minutes)**
Course work: successful completion of lab tasks
*The exact examination modalities will be announced by the 2nd event at the latest.

6 Forms of examination and performance
☒ *Module exam* ☐ Part of modular exam

7 Participation requirements
None. Basic knowledge of digital communications and electromagnetic wave propagation is recommended.

8 Module type and usability of the module
Elective Class in the Master's degree program Sustainable Energy Systems.

9 Module Supervisor	**Faculty in charge**
Prof. Dr.-Ing. Christian Wietfeld	Faculty of Electrical Engineering and Information Technology

<table>
<tr><td colspan="7">Module 2-50 Mobile Radio Networks 2: Advanced Network Concepts ETIT-408</td></tr>
<tr><td colspan="2">Rota
anually at SS</td><td>Duration
1 Semester</td><td>Semester
2nd Semester</td><td>Credits
5</td><td>Presence
35 h</td><td>Self-Study Load
115 h</td></tr>
<tr><td>1</td><td colspan="6">Module Structure
<table>
<tr><th>No.</th><th>Element / Course</th><th>LSF-No.</th><th>Type</th><th>SWS</th></tr>
<tr><td>1</td><td>Mobile Radio Networks 2: Advanced Network Concepts: Lecture</td><td>XXX</td><td>V</td><td>2</td></tr>
<tr><td>2</td><td>Mobile Radio Networks 2: Advanced Network Concepts: Lab Course</td><td>XXX</td><td>P</td><td>1</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="6">Language
English</td></tr>
<tr><td>3</td><td colspan="6">Content
1. Local radio networks (WLAN/Wi-Fi, WPAN, Mesh, DECT)
2. Wireless Internet of Things networks (Low Power Wide Area Networks, Cellular-IoT)
3. Advanced features of 4G and 5G networks (Carrier Aggregation, Device-to-Device, Network Slicing, Beamforming, Ultra Reliable and Low Latency Communications)
4. Satellite networks, Aerial Wireless Networks
5. Future mobile network concepts for 5G-Advanced and 6G (e.g. mmWave/THz spectrum, Reflective Intelligent Surfaces, Integration of Artificial Intelligence)

The discussion of theoretical content is complemented by practical demonstrations and by case studies on ongoing research and business aspects of mobile radio networks.

Literature (respective latest version)
Liberg, Olof, et al. Cellular Internet of Things: From Massive Deployments to Critical 5G Applications. Academic Press, 2019.
Dahlmann, E.; Parkvall, S.; Sköld, J.: 4G: LTE/LTE-Advanced for Mobile Broadband, Academic Press
P. Marsch, A. Osseiran, J.F. Monserrat, 5G Mobile and Wireless Communications Technology, Cambridge University Press</td></tr>
<tr><td>4</td><td colspan="6">Competencies
Upon successful completion of the module, students understand advanced and upcoming mobile radio network concepts and terminology which enables them to characterize research-related challenges of integrating the considered features, assess the feasibility, and to develop design solutions according to design goals. Students further deepen their knowledge base on specific network designs for particular fields of application, and to make a technically sound selection.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of advanced mobile radio networks, this includes, for example, raising awareness of socially relevant topics such as age and technology or data security and digital participation.</td></tr>
<tr><td>5</td><td colspan="6">Examination
Module exam: oral exam (max. 40 minutes) or written exam (max. 180 minutes)*
Course work: successful completion of lab tasks
*The exact examination modalities will be announced by the 2nd event at the latest.</td></tr>
<tr><td>6</td><td colspan="6">Forms of examination and performance
☒ Module exam ☐ Part of modular exam</td></tr>
<tr><td>7</td><td colspan="6">Participation requirements
None. Basic knowledge of mobile radio networks is recommended.</td></tr>
<tr><td>8</td><td colspan="6">Module type and usability of the module
Elective Class in the Master's degree program Sustainable Energy Systems.</td></tr>
<tr><td>9</td><td colspan="3">Module Supervisor
Prof. Dr.-Ing. Christian Wietfeld</td><td colspan="3">Faculty in charge
Faculty of Electrical Engineering and Information Technology</td></tr>
</table>

<table>
<tr><td colspan="7">Modul 2-25: Modeling and Control of Robotic Manipulators ETIT-244</td></tr>
<tr><td colspan="2">Turnus
Annually at WS</td><td>Duration
1 Semester</td><td>Study section
3rd Semester</td><td>LP
5</td><td>Attendance rate
35 h</td><td>Self-study
115 h</td></tr>
<tr><td>1</td><td colspan="6">Module structure
<table>
<tr><th>Nr.</th><th>Element / Course</th><th>LSF no.</th><th>Typ</th><th>SWS</th></tr>
<tr><td>1</td><td>Modeling and Control of Robotic Manipulators (lecture)</td><td>08 0125</td><td>V</td><td>2</td></tr>
<tr><td>2</td><td>Modeling and Control of Robotic Manipulators (tutorial)</td><td>08 0126</td><td>Ü</td><td>1</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="6">Course language
Englisch</td></tr>
<tr><td>3</td><td colspan="6">Lehrinhalte
1. Spatial Representations
2. Direct Kinematics
3. Differential Kinematics
4. Dynamics
5. Actuators and Sensors
6. Motion Control
7. Interaction Control
8. Robotics System Toolbox and ROS

Literature
Siciliano, Sciavicco: Robotics: Modelling, Planning and Control (alternativ: Sciavicco, Siciliano: Modelling and Control of Robot Manipulators)
Siciliano, Khatib: Springer Handbook of Robotics</td></tr>
<tr><td>4</td><td colspan="6">Competencies
This course provides the students with a profound background of modelling, planning and control of robotic manipulators.
The students acquire practical experience in robot kinematics, dynamics and motion control under ROS/Matlab.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of modeling and control of robotic manipulators, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy and sustainability.</td></tr>
<tr><td>5</td><td colspan="6">Exams
Module Exam: oral exam (max. 40 minutes) or written exam (max. 180 minutes)*

* The exact examination modalities will be announced by the 2nd event at the latest.</td></tr>
<tr><td>6</td><td colspan="6">Forms of examination and performance
☒ Module Exam ☐ Partial achievements</td></tr>
<tr><td>7</td><td colspan="6">Participation requirements
Keine</td></tr>
<tr><td>8</td><td colspan="6">Module type and usability of the module
Elective Class in the Master's degree program Sustainable Energy Systems .</td></tr>
<tr><td>9</td><td colspan="3">Module Supervisor
apl. Prof. Dr. rer. nat. Frank Hoffmann</td><td colspan="3">Faculty in charge
Faculty of Electrical Engineering and Information Technology</td></tr>
</table>

Modul 3-43: Automated Driving					ETIT-504
Turnus Annually at WS	**Duration** 1 Semester	**Study section** 3rd Semester	**LP** 5	**Attendance rate** 35 h	**Self-study** 115 h

1 Module structure

Nr.	Element / Course	LSF no.	Typ	SWS
1	Automated Driving (lecture)	08 0215	V	2
2	Automated Driving (tutorial)	08 0216	Ü	1

2 Course language
English

3 Lehrinhalte

1. Exteroceptive sensors (camera, radar, lidar, ultrasonic, sensor fusion)
2. Conidtional, highly, and fully automated driving:
   a. Situation analysis and interaction-aware trajectory prediction
   b. Trajectory planning and coupled prediction and planning
   c. Control concepts to follow a planned trajectory
3. Machine learning in automated driving
4. Driver monitoring and hand-over models

Literature:
I. Goodfellow, Y. Bengio, A. Courville: Deep Learning (MIT Press)
D. Forsyth, J. Ponce (Ed.): Computer Vision: A Modern Approach (Prentice Hall)
selected papers on automated driving, robotics, and deep learning

4 Competencies
The students acquire a profound knowledge of automated driving systems. They are able to understand and solve tasks on perception, prediction, planning, control, and driver modelling with appropriate methods.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of automated driving systems, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy and sustainability.

5 Exams
Module Exam: oral exam (max. 40 minutes) or written exam (max. 180 minutes)*

* The exact examination modalities will be announced by the 2nd event at the latest.

6 Prüfungsformen und -leistungen
☒ Module Exam ☐ Partial achievements

7 Participation requirements
Recommended prerequisites: Basic knowledge of mechatronics, mechanics

8 Module type and usability of the module
Elective Class in the Master's degree program Sustainable Energy Systems.

9 Module Supervisor	**Faculty in charge**
Prof. Dr.-Ing. Prof. h.c. Dr. h.c. Torsten Bertram	Faculty of Electrical Engineering and Information Technology

Modul 3-47: Simulation and Testing Methods for Modern Power Systems						ETIT-507
Turnus Jährlich zum WS	**Dauer** 1 Semester	**Studienabschnitt** 2./3. Semester	**LP** 5	**Präsenzanteil** 35 h		**Eigenstudium** 115 h

1 Modulstruktur

Nr.	Element / Lehrveranstaltung	LSF-Nr.	Typ	SWS
1	Simulation and Testing Methods for Modern Power Systems Lecture		V	2
2	Simulation and Testing Methods for Modern Power Systems Practical Works		P	1

2 Lehrveranstaltungssprache
Englisch

3 Lehrinhalte
1. Real-time simulation of power systems
2. Hardware-in-the-loop (HIL) simulation and testing
3. Controller hardware-in-the-loop (CHIL)
4. Power hardware-in-the-loop (PHIL)
5. Electrical design of low-voltage laboratory testbeds
6. Praxis-relevant applications of modern testing

Literatur
N. Watson and J. Arrillaga, *Power Systems Electromagnetic Transients Simulation*. London: The Institution of Engineering and Technology, 2003.

J. A. Martinez-Velasco, *Transient Analysis of Power Systems*. Wiley-IEEE Press, 2020.

4 Kompetenzen
The aim of the lecture is to deliver comprehensive knowledge on advanced simulation and testing methods for modern power systems, covering both theoretical aspects and practical applications.
After completing the lecture, students can independently design and implement complex simulations and hardware testbeds for testing modern components in power systems (Battery Storage Systems, EV-charging stations, power converters, etc.), apply innovative testing methods, and choose appropriate tools and devices for specific requirements.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of simulation and testing methods for modern power systems, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy and sustainability.

5 Prüfungen
Modulprüfung: Oral exam (max. 45 minutes) or written exam (max. 120 minutes) *
Studienleistungen: Active participation in practical works (laboratory tasks, presentations, etc.,) is also a prerequisite to participate in the examination

* The mode of the examination will be announced within two weeks after the start of the lecture.

6 Prüfungsformen und –leistungen
☒ Modulprüfung ☐ Teilleistungen

7 Teilnahmevoraussetzungen
Basic knowledge in Electrical Energy Engineering and Control Systems

8 Modultyp und Verwendbarkeit des Moduls
Elective Class in the Master's degree program Sustainable Energy Systems, *Energy Systems Cataloque.*

9 Modulbeauftragte/r	**Zuständige Fakultät**
Dr.-Ing. Alfio Spina	Faculty of Electrical engineering and Information Technology

3rd Semester

<table>
<tr><td colspan="6">Industrial Internship ETIT-282</td></tr>
<tr><td>Turnus
none</td><td>Duration
12 weeks</td><td>Study section
3rd Semester</td><td>LP
14</td><td colspan="2">Aufwand
12 weeks</td></tr>
<tr><td>1</td><td colspan="5">Module structure
<table>
<tr><th>Nr.</th><th>Element / Course</th><th>Typ</th><th>Credits</th><th>Time hours</th></tr>
<tr><td>1</td><td>Industrial Internship</td><td>P</td><td>14</td><td>420</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="5">Course language
Englisch</td></tr>
<tr><td>3</td><td colspan="5">Teaching Content
The industrial internship takes place in the following areas:
• Research and development,
• Project planning, design, manufacture, assembly, testing and commissioning,
• Operation and maintenance,
• Marketing, sales, operational organisation, management and training
The Internship Office of the Department of Electrical Engineering and Information Technology advises each student on the selection of an internship company and the implementation of the internship. The advice and support includes, in particular, the curricular fit of the internship area offered by the internship company with the student's chosen major. The professional assessment and evaluation of the industrial internship is carried out for each student by a university lecturer of the faculty.</td></tr>
<tr><td>4</td><td colspan="5">Competencies
After successful completion of the industrial internship, the students have an insight into the operational processes and organisation in industry as well as into the social structures of companies. Furthermore, they know typical engineering tasks in research and development and/or in production and operation. Finally, they have knowledge of practical procedures in industrial production and/or the use of modern technologies in electrical power engineering. By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility.</td></tr>
<tr><td>5</td><td colspan="5">Exams
A report book must be prepared on the internship. The evaluation of success and performance is based on the submitted reports (submitted electronically as PDF) and the internship certificate of the company.</td></tr>
<tr><td>6</td><td colspan="5">Forms of examination and performance
☐ Module Exam ☐ Partial achievements</td></tr>
<tr><td>7</td><td colspan="5">Participation requirements
Recommended knowledge: Knowledge to perform engineering related activities</td></tr>
<tr><td>8</td><td colspan="5">Module type and usability of the module
Industrial internship in the Master's degree programme "Sustainable Energy Systems"</td></tr>
<tr><td>9</td><td colspan="2">Module Supervisor
Prof. Dr.-Ing. Christian Rehtanz</td><td colspan="3">Faculty in charge
Faculty of Electrical Engineering and Information Technology</td></tr>
</table>

<table>
<tr><td colspan="7">Lab Course ETIT-20P</td></tr>
<tr><td colspan="2">Turnus
Half-yearly</td><td>Duration
1 Semester each</td><td>Study section
3rdSemester</td><td>LP
6</td><td>Attendance rate
90 h</td><td>Self-study
90 h</td></tr>
<tr><td>1</td><td colspan="6">Module structure
<table>
<tr><th>Nr.</th><th>Element / Course</th><th>LSF no.</th><th>Typ</th><th>CP</th><th>Time hours</th></tr>
<tr><td>1</td><td>Lab Course 1</td><td></td><td>P</td><td>3</td><td>45</td></tr>
<tr><td>2</td><td>Lab Course 2</td><td></td><td>P</td><td>3</td><td>45</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="6">Course language
English</td></tr>
<tr><td>3</td><td colspan="6">Lehrinhalte
The students complete 2 compulsory elective internships from the range of courses offered by the faculty.
If internships with a total of 6 LP are available, only one internship is to be completed.
The exact descriptions and information on the internships can be found in the following internship descriptions 1-18 or on the Internet.</td></tr>
<tr><td>4</td><td colspan="6">Competencies
After successful completion of the course, students are able to
discuss different perspectives on an engineering problem and explain their own views.
and to explain their own views. The students are able to structure larger tasks during a group work phase and to derive meaningful work packages. Furthermore, the students understand the methodological approaches and procedures in the context of scientific work in engineering and can apply these to different problems.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility.</td></tr>
<tr><td>5</td><td colspan="6">Exams
The examination requirements are deposited in the respective internship descriptions.</td></tr>
<tr><td>6</td><td colspan="6">Forms of examination and performance
☐ Module Exam ☒ Partial achievements</td></tr>
<tr><td>7</td><td colspan="6">Participation requirements
The participation requirements are listed in the respective internship descriptions.
The number of participants is limited. Admission to participation is in accordance with § 9 of the examination regulations.</td></tr>
<tr><td>8</td><td colspan="6">Module type and usability of the module
c</td></tr>
<tr><td>9</td><td colspan="3">Module Supervisor
Dean of the Faculty of Electrical Engineering and Information Technology</td><td colspan="3">Faculty in charge
Faculty of Electrical Engineering and Information Technology</td></tr>
</table>

<table>
<tr><td colspan="7">LAB 1: Electromagnetic Field Theory Simulation ETIT-211</td></tr>
<tr><td colspan="2">Turnus
Annually at WS</td><td>Duration
2 Weeks (Block event)</td><td>Study section
3rd Semester</td><td>LP
3</td><td>Attendance rate
60 h</td><td>Self-study
30 h</td></tr>
<tr><td>1</td><td colspan="6">Module structure
<table>
<tr><th>Nr.</th><th>Element / Course</th><th>LSF no.</th><th>Typ</th><th>Zeitstunden</th></tr>
<tr><td>1</td><td>Lab</td><td>08 0023</td><td>P</td><td>90</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="6">Course language
English</td></tr>
<tr><td>3</td><td colspan="6">Teaching Content
1. introduction to the functioning and procedure of numerical field calculation programmes.
2. theory of the numerical methods of field calculation on which the programmes are based
3. transferring electrical engineering problems into suitable calculation models
4. utilisation of symmetry properties, special features of discretisation (calculation accuracy/ duration), types of boundary conditions and degrees of freedom
5. simulation and calculation of selected problems (two-dimensional, rotationally symmetrical) for time-dependent and independent fields, respectively.
6. functional verification and comparison of numerical solutions with analytical calculation results (if possible)
7. export of obtained simulation results for further numerical and graphical processin
Literature
Kost: Numerische Methoden in der Berechnung elektromagnetischer Felder</td></tr>
<tr><td>4</td><td colspan="6">Competencies
After successful completion of the practical course, the students have acquired basic knowledge about the possibilities and limitations of field calculation programs. They are able to transfer real field-theoretical problems into a calculable arrangement. They also have knowledge that enables them to reduce the computational effort to a necessary level through suitable measures and to assess the quality of a simulation result obtained in this way.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of field theoretical simulation, this includes, for example, raising awareness of socially relevant topics such as age and technology or data security and digital participation.</td></tr>
<tr><td>5</td><td colspan="6">Exams
Successful completion of 70% of the internship tasks</td></tr>
<tr><td>6</td><td colspan="6">Forms of examination and performance
☐ Module Exam ☒ Partial achievements</td></tr>
<tr><td>7</td><td colspan="6">Participation requirements
Recommended prerequisites: Knowledge of the basics of
Electrical Engineering, Basic Mathematical Knowledge of Numerical Calculation.
The number of participants is limited. Admission to participation is in accordance with § 9 of the examination regulations.</td></tr>
<tr><td>8</td><td colspan="6">Module type and usability of the module
Elective Lab in the Master's degree program Sustainable Energy Systems.</td></tr>
<tr><td>9</td><td colspan="3">Module Supervisor
Prof. Dr.-Ing. Frank Jenau</td><td colspan="3">Faculty in charge
Faculty of Electrical Engineering and Information Technology</td></tr>
</table>

<table>
<tr><td colspan="7">LAB 2: Simulative performance evaluation of communication networks ETIT-214</td></tr>
<tr><td colspan="2">Turnus
Annually at WS</td><td>Duration
2 weeks (block event)</td><td>Study section
3rd Semester</td><td>CP
3</td><td>Attendance rate
48 h</td><td>Self-study
42 h</td></tr>
<tr><td>1</td><td colspan="6">Module structure
<table>
<tr><th>Nr.</th><th>Element / Course</th><th>LSF no.</th><th>Typ</th><th>Zeitstunden</th></tr>
<tr><td>1</td><td>Lab</td><td>08 0138</td><td>P</td><td>90</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="6">Course language
English</td></tr>
<tr><td>3</td><td colspan="6">Teaching Content
1. develop the required basics of OMNeT++
a. Simulation setup
b. Module and simulation definition/declaration
c. Simulation of simple communication networks
2. modelling of system properties
a. Modelling of communication protocols (ISO/OSI)
b. Consideration of mobility aspects on OMNeT++
c. Modelling and consideration of communication channel properties
d. Implementation of complete system scenarios
3. evaluation and optimisation of complex communication systems
a. Simulation of dynamic communication networks
b. Tools for statistical analysis
c. Validation of obtained results
Literature
Peterson, Davie: Computer Networks, 4th Edition;
Sinclair: Simulation of Computer Systems and Computer Networks</td></tr>
<tr><td>A</td><td colspan="6">Competencies
After successful completion of the practical course, the students have a sound knowledge of the performance evaluation and dimensioning of communication systems by means of event-driven simulation. In addition to the actual functions of the OMNeT++ simulation environment, this also includes the implementation and highly accurate simulative realisation of protocol-based processes in communication systems. The graduates of this practical course will be able to abstract even complex networking scenarios and map them realistically in the OMNeT++ simulation environment. Furthermore, the results obtained in this way can be processed accordingly and used for performance evaluation or optimisation based on aspects relevant to communication technology.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of simulative performance evaluation of communication networks, this includes, for example, raising awareness of socially relevant topics such as age and technology or data security and digital participation.</td></tr>
<tr><td>5</td><td colspan="6">Exams
Successful completion of at least 80% of the tasks set.</td></tr>
<tr><td>6</td><td colspan="6">Forms of examination and performance
☐ Module Exam ☒ Partial achievements</td></tr>
<tr><td>7</td><td colspan="6">Participation requirements
The number of participants is limited. Admission to participation is in accordance with § 9 of the examination regulations.</td></tr>
<tr><td>8</td><td colspan="6">Module type and usability of the module
Elective Lab in the Master's degree program Sustainable Energy Systems.</td></tr>
</table>

9	**Module Supervisor** Prof. Dr.-Ing. Christian Wietfeld	**Faculty in charge** Faculty of Electrical Engineering and Information Technology

<table>
<tr><td colspan="7">LAB 3: Simulation and control of robot systems ETIT-216</td></tr>
<tr><td colspan="2">Turnus
Annually at WS</td><td>Duration
1 Semester</td><td>Study section
3rd Semester</td><td>LP
3</td><td>Attendance rate
48 h</td><td>Self-study
42 h</td></tr>
<tr><td>1</td><td colspan="6">Module structure
<table>
<tr><th>Nr.</th><th>Element / Course</th><th>LSF no.</th><th>Typ</th><th>SWS</th></tr>
<tr><td>1</td><td>Lab</td><td>08 0022</td><td>P</td><td>4</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="6">Course language
English</td></tr>
<tr><td>3</td><td colspan="6">Teaching Content
1. basic competence: Matlab, Simulink, Robotic Toolbox, Virtual Reality
2. attempt: Modelling, kinematics and dynamics
3. experiment: path planning and control
4. experiment: image-based control
Literature
Bode: Systeme der Regelungstechnik mit MATLAB und Simulink;
Angermann, Beuschel, Rau, Wohlfarth: Matlab – Simulink – Stateflow: Grundlagen, Toolboxen, Beispiele;
Siciliano, Sciavicco, Villani, Oriolo: Robotics – Modelling, Planning and Control;</td></tr>
<tr><td>4</td><td colspan="6">Competencies
After successful completion of the practical course, the students master the essential practical basics and methods for modelling and simulating robotic systems. The students are able to classify tasks in robotics and solve them independently; they have in-depth knowledge of the control and regulation of robotic manipulators through practical application.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of modelling and simulation of robot systems, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy and sustainability.</td></tr>
<tr><td>5</td><td colspan="6">Exams
The supervisor checks the completion of all subtasks and the protocol during the event.</td></tr>
<tr><td>6</td><td colspan="6">Forms of examination and performance
☐ Module Exam ☒ Partial achievements</td></tr>
<tr><td>7</td><td colspan="6">Participation requirements
The number of participants is limited. Admission to participation is in accordance with § 9 of the examination regulations.</td></tr>
<tr><td>8</td><td colspan="6">Module type and usability of the module
Elective Lab in the Master's degree program Sustainable Energy Systems.</td></tr>
<tr><td>9</td><td colspan="3">Module Supervisor
Prof. Dr.-Ing. Prof. h.c. Dr. h.c. Torsten Bertram</td><td colspan="3">Faculty in charge
Faculty of Electrical Engineering and Information Technology</td></tr>
</table>

<table>
<tr><td colspan="7">LAB 4: Programming Reconfigurable Hardware ETIT-350</td></tr>
<tr><td colspan="2">Turnus
Annually at WS</td><td>Duration
1 Semes-ter</td><td>Study section
3rd Semester</td><td>LP
3</td><td>Attendance rate
45 h</td><td>Self-study
45 h</td></tr>
<tr><td>1</td><td colspan="6">Module structure
<table>
<tr><th>Nr.</th><th>Element / Course</th><th>LSF no.</th><th>Typ</th><th>SWS</th></tr>
<tr><td>1</td><td>Lab</td><td>080333</td><td>P</td><td>4</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="6">Course language
Englisch</td></tr>
<tr><td>3</td><td colspan="6">Teaching Content
- Design of Hardware Circuit and Logics on FPGAs
- Usage of Design and EDA Tools
- Practical working with FPGA Plattforms
- VHDL Programming

Literature
[1] „ Digital Electronics with DIGILENT BASYS 2 & 3 FPGA Boards “, Andrzej J. Gapinski, Lap Lambert Academic Publishing, 2018, ISBN 9786139929764</td></tr>
<tr><td>4</td><td colspan="6">Competencies
By attending this course, students will learn how to work with current FPGA Architectures and Boards. The fundamentals in the usage of tools and programming VHDL will be shown.
In multiple practical lessons, VHDL and Xilinx Vivado will be used to implement hardware designs for different tasks. The students will implement practical exercises on a Basys3 Development Board with an Artix 7 FPGA.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of reconfigurable hardware, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy and sustainability.</td></tr>
<tr><td>5</td><td colspan="6">Exams
Successful completion of 70% of the internship tasks</td></tr>
<tr><td>6</td><td colspan="6">Forms of examination and performance
☐ Module Exam ☒ Partial achievements</td></tr>
<tr><td>7</td><td colspan="6">Participation requirements
Recommended prerequisite:
Basic knowledge of computer architectures,
Basic knowledge of VHDL programming

The number of participants is limited. Admission to participation is in accordance with § 9 of the examination regulations.</td></tr>
<tr><td>8</td><td colspan="6">Module type and usability of the module
Elective Lab in the Master's degree program Sustainable Energy Systems.</td></tr>
<tr><td>9</td><td colspan="3">Module Supervisor
Prof. Dr.-Ing. Stephan Frei</td><td colspan="3">Faculty in charge
Faculty of Electrical Engineering and Information Technology</td></tr>
</table>

LAB 5: Control system operation for electrical power grids						ETIT-351
Turnus Annually at WS	**Duration** 1 Semes-ter	**Study section** 3rd Semester	**LP** 3	**Attendance rate** 45 h	**Self-study** 45 h	

1 Module structure

Nr.	Element / Course	LSF no.	Typ	SWS
1	Lab	08XXXX	P	4

2 Course language
English

3
Control systems are the man-machine interface between the electrical energy transmission system and the actions necessary to keep the system stable and safe throughout the day. Uncertainties due to grid users and volatile renewable energies as well as disturbances in the grid and generation must be monitored and handled appropriately.

Teaching Content
1. introduction to the control centre operation of electrical transmission networks
2. operation of a realistic control system
3. carrying out network operation management for regular operating situations on the control centre simulator
4. carrying out network operations for disturbed operating situations on the control centre simulator

Literature
Kundur: Power System Stability and Control

4 Competencies
After successful completion of the practical course, the students have acquired basic knowledge of control system operation for electrical power grids. They are able to guide a power grid through various normal and disturbed operating situations on the control centre simulator. This creates a deep understanding of the real control system in practice.
Today's possibilities are taught during the practical course using a realistic control system with which the grid operation management personnel are also trained for practice and tried out using operating situations.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of control system operation for electrical power grids, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy and sustainability.

5 Exams
Completion of all subtasks and preparation of a protocol.

6 Forms of examination and performance
☐ Module Exam ☒ Partial achievements

7 Participation requirements
Recommended prerequisites: Knowledge of the basics of electrical power engineering, knowledge of information systems for grid operation management.

The number of participants is limited. Admission to participation is in accordance with § 9 of the examination regulations.

8 Module type and usability of the module
Elective Lab in the Master's degree program Sustainable Energy Systems.

9 Module Supervisor	**Faculty in charge**
Dr.-Ing. Ulf Häger	Faculty of Electrical Engineering and Information Technology

<table>
<tr><td colspan="7">LAB 6: High Performance Computing in Python ETIT-354</td></tr>
<tr><td colspan="2">Turnus
annually in WS</td><td>Duration
2 weeks (block event)</td><td>Study section
3rd semester</td><td>LP
3</td><td>Attendance rate
48 h</td><td>Self-study
42 h</td></tr>
<tr><td>1</td><td colspan="6">Module structure
<table>
<tr><th>Nr.</th><th>Element / Course</th><th>LSF no.</th><th>Typ</th><th>Zeitstunden</th></tr>
<tr><td>1</td><td>Lab</td><td>08 XXXX</td><td>P</td><td>90</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="6">Course language
English</td></tr>
<tr><td>3</td><td colspan="6">Lehrinhalte
1. Concepts for evaluating the performance of implemented algorithms (Profiling)
2. Computational efficient algorithms and application of multiprocessing for speed improvement
3. Distributed programming for clusters or networked computers utilizing Pyro
4. Connection of existing system via the application of Numba, PyPy, f2py
5. NumPy for fast computations
6. Cython for speed improvements
7. Speeding up an existing loop using OpenMP by building modules for parallelization
8. Examplary implementation and evaluation of an algorithm for the design of quantum devices

Literature
Gorelick, Ozswald: High Performance Python</td></tr>
<tr><td>4</td><td colspan="6">Competencies
Students gain practical knowledge of developing procedures for the implementation of high performance computing algorithms. They learn about the practical behavior and how the performance characteristics of high performance computing systems can be evaluated as well as what the limits of a hardware-oriented simulation are. Furthermore, students will have gained the essentials of the open-source software framework Python for the realization of high performance computing in engineering applications. They will be able to speed up algorithms for fast computation.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus take on social responsibility. In the area of high performance computing in Python, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy and sustainability.</td></tr>
<tr><td>5</td><td colspan="6">Exams
The Supervisor checks the completion and the reports of all subtasks during the course.</td></tr>
<tr><td>6</td><td colspan="6">Forms of examination and performance
☐ Module Exam ☒ Partial achievements</td></tr>
<tr><td>7</td><td colspan="6">Participation requirements
Basic knowledge in programming.
The number of participants is limited. Admission to participation is in accordance with § 9 of the examination regulations.</td></tr>
<tr><td>8</td><td colspan="6">Module type and usability of the module
Elective Lab in the Master's degree program Sustainable Energy Systems.</td></tr>
<tr><td>9</td><td colspan="3">Module Supervisor
apl. Prof. Dr.-Ing. Dirk Schulz</td><td colspan="3">Faculty in charge
Faculty of Electrical Engineering and Information Technology</td></tr>
</table>

Advanced Seminar (Oberseminar)					ETIT-281
Turnus Half-yearly	**Duration** 1 Semester	**Study section** 3rd Semester	**LP** 5	**Attendance rate** 25 h	**Self-study** 65 h

1 Module structure

Nr.	Element / Course	LSF no.	Typ	SWS
1	Course Scientific Work: Paper reading		S	2
2	Seminar Scientific Work		S	2

2 Course language
Englisch

3 Teaching content part 1
1. research and selection
2. classification and elaboration
3. summary of contents

Teaching content Abschnitt 2
1. elaboration of the content of scientific papers
2. presentation of scientific work to an expert audience
3. discussion of scientific theses and results with an expert audience

The subject from which the scientific topic originates depends on the subject area of the upper seminar.

4 Competencies
Students can familiarise themselves with a scientific publication and are able to place the publication in the overall context of the respective field. They can present the content of the publication to an expert audience, answer questions about the content of this publication and discuss the conclusions from this publication with an expert audience. To this end, they are proficient in the presentation techniques customary in scientific lectures. In addition, they can participate in the discussion about the contents of a scientific lecture from their subject area.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus take on social responsibility.

5 Exams
The student's final presentation is the Module Exam. In addition, the student must actively participate in at least five presentations by other students as coursework.

6 Forms of examination and performance
☒ Module Exam ☐ Partial achievements

7 Participation requirements
Recommended prerequisites: Good technical knowledge in the respective field of the upper seminar.

8 Module type and usability of the module
Elective Course in the Master's degree program Sustainable Energy Systems.

9 Module Supervisor	**Faculty in charge**
Dean of the Faculty of Electrical Engineering and Information Technology	Faculty of Electrical Engineering and Information Technology

Master Thesis

With the Master's thesis, 30 credit points must be successfully acquired.

Modul 4-1: Master Thesis (Masterarbeit)					ETIT-290
Turnus Half-yearly	**Duration** 1 Semester	**Study section** 4th Semester	**LP** 30	**Attendance rate** -	**Self-study** 900 h

1 Module structure

Nr.	Element / Course	LSF no.	Typ	SWS
1	Master Thesis		P	-

2 Course language
English

3 Teaching Content
1. familiarisation with the scientific problem of the task using guidelines.
2. analysis of the relevant previous scientific work
3. development of solution approaches
4. verification and evaluation of the solution approaches
5. selection and realisation of the best approach
6. scientific description of the methodology and the solution in written form.

The contents and results of the Master's thesis must be processed and presented to an expert audience. The presentation must take place no later than 6 weeks after submission of the thesis.

4 Competencies
The student is able to work independently on a narrowly defined technical-scientific problem from his or her subject area using scientific methods. He or she is able to evaluate relevant preliminary work from the specialist literature, develop new approaches to solutions, evaluate these and finally implement a solution. Furthermore, he or she is able to present the results in writing in a structured way so that the relevant aspects of the solution are understood. The student is also able to present the results to a specialist audience and discuss them at the end.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility.

5 Exams
The Master's thesis counts as a Module Exam.

6 Forms of examination and performance
☒ Module Exam ☐ Partial achievements

7 Participation requirements
Recommended prerequisites: Good scientific knowledge in the respective field of the master thesis
Required prerequisites: Acquisition of 80 credit points in the Master's programme.

8 Module type and usability of the module
Elective Module in the Master's degree program Sustainable Energy Systems.

9	**Module Supervisor**	**Faculty in charge**
	Dean of the Faculty of Electrical Engineering and Information Technology	Faculty of Electrical Engineering and Information Technology

Version information

V 1.0: Version of the module handbook adopted by the Department Council of the Faculty of Electrical Engineering and Information Technology on 03/05/2023

Change compared to the version dated 03/05/2023

- The content of the modules Design of Sustainable Products & Services, Energy Economics and Technologies, Power System Operation and Stability, Planning and Operation of Distributed Energy Sources, Principles of Sustainability Power System Economics, Control system operation for electrical power grids and Electromagnetic field theory simulation has been revised.
- The elective module Simulation and Testing Methods for Modern Power Systems has been added.
- The social commitment anchored in the study program has been added to the descriptions at module level.
- Language corrections.

Information on the elective modules

Two subject-related modules of 3 SWS each (usually corresponds to 5 LP) can be completed by a joint module examination. In this way, 10 credit points are acquired. There are a number of sensible combinations for this, which can be requested from the respective professors in individual cases.