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2020

HOCHSCHULE COBURG

Module Manual

FOR THE BACHELOR PROGRAM
POWER ENGINEERING AND RENEWABLE ENERGIES (EN)
DEPARTMENT OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Study plan for the bachelor's degree program **Power Engineering and Renewable Energies**

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Notes: The numbers above the course overview indicate the number of ECTS credit points. There is a total of 210 ECTS points.
The number of Semester Week Hours = SWH is indicated in the syllabus.

Preliminary remarks

One ECTS credit point according to the "European Credit and Accumulation Transfer System" corresponds to a workload of 30 hours per semester.

The explanation of the formal admission requirements for the individual modules can be found in the Study and Examination Regulations (SPO) of the academic program.

Please note:

The module handbook lists all modules for which examinations are offered in the respective semester, but they do not necessarily have to be taught in this semester.

Compulsory elective modules:

According to the curriculum, subject-specific compulsory and compulsory elective modules can also be taken as subject-specific compulsory elective modules, which are offered for the study programs Automation Engineering and Robotics (AU), Electrical Engineering and Information Technology (EL), and Computer Science (IF). More information on the compulsory elective modules offered by other degree programs can also be found in the corresponding module manuals.

Risk assessment according to §10 Maternity Protection Act:

For each module there is an independent risk assessment according to §§ 10 et seqq. Maternity Protection Act (*MuSchG*). The modules are assessed according to
green = "no selection restrictions"
yellow = "some selection restrictions, individual agreement necessary"
red = "not selectable according to *MuSchG*"

The individual risk assessments can be found in the corresponding laboratories.

The central contact point for advice for pregnant or breastfeeding students is the family office of the Coburg University of Applied Sciences. Here you will also find an overview of risk assessment.

Table of Contents

1. Basic studies

Module name	**Business Administration 1**
Abbrev.	Bwl1
Format / SWH	Seminar-type lectures / 2 SWH
Credit points	2.5 ECTS
Work requirement	Total: 75 hrs, of which in-class: 30 hrs, self-study: 45 hrs.
Semester	1
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Georg Roth
Instructor(s)	Dipl. Betriebswirtin (FH) Nicole Strehl
Language	German
Use in other academic programs	AU, EL and EN
Admission requirements	None
Prerequisites	None
Qualification objectives / skills	Students will gain knowledge of essential basic concepts of general business administration and selected correlations from the following areas: legal forms, organization theory, personnel, strategic corporate policy, marketing.
Course contents	**Basic concepts of general business administration** **Purpose and objectives of** **companies** **Legal forms** (corporations, partnerships, and mixed forms) and their business relevance Corporate Governance and its social significance **Organization of companies** - Importance of the structural and process organization - Forms of organization in detail

	- Issues related to the improvement of process organization - Positions and job definition **Fundamental issues in human resources management** Significance and responsibilities of today's human resources management **Basic concepts in marketing** - Marketing strategies - Tools of the marketing mixes and their significance - Significance of customer loyalty and CRM
Study / examination grades contributing to final grade	Written partial examination (60 minutes)
Other performance tests	None
Media:	Projector, blackboard, overhead projector, self-directed study
Literature:	Känel, von Siegfried: Betriebswirtschaft für Ingenieure, Herne, NWB-Verlag, 2008 Schmalen, Helmut; Pechtl, Hans: Grundlagen und Probleme der Betriebswirtschaft, 14th edition, Stuttgart, Verlag Schäffer-Poeschel 2009 Wöhe, G.: Einführung in die Allgemeine Betriebswirtschaftslehre, 24th revised edition, Munich, Verlag Vahlen, 2010

Module name	**Business Administration 2**
Abbrev.	Bwl2
Format / SWH	Seminar-type lectures / 2 SWH
Credit points	2.5 ECTS
Work requirement	Total: 75 hrs, of which in-class: 30 hrs, self-study: 45 hrs.
Semester	2
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Georg Roth
Instructor(s)	Dipl. Betriebswirtin (FH) Nicole Strehl
Language	German
Use in other academic programs	AU, EL and EN
Admission requirements	None
Prerequisites	None
Qualification objectives / skills	Students will gain knowledge of essential basic concepts of general business administration and selected correlations from the following areas: production management, supply planning, ecology management, investment and financing, accounting
Course contents	**Foundations of production management** - Production factors, production processes, products - Work planning - Quality management **Supply planning** - Conceptual delimitation and tasks of procurement - Provision of human capital (covering personnel requirements) - Provision of resources and consumption factors - Special aspects about the provision of resources (depreciation methods)

	- Special aspects about the provision of consumption factors **Ecological management** **Fundamentals of investment and financing accounting** - Investment types - Main forms of financing - Static accounting procedures - Dynamic calculation methods **Fundamentals of accounting** - Structure and subareas of accounting - Tasks of accounting - Annual financial report with balance sheet and profit and loss statement **Fundamentals of strategic corporate policy** - Goals and instruments • Strengths-weaknesses analysis • Experience curve analysis • Product life-cycle analysis • Portfolio analysis
Study / examination grades contributing to final grade	Written partial examination (60 minutes)
Other performance tests	None
Media:	Projector, blackboard, overhead projector, self-directed study
Literature:	Känel, von Siegfried: Betriebswirtschaft für Ingenieure, Herne, NWB-Verlag, 2008 Schmalen, Helmut; Pechtl, Hans: Grundlagen und Probleme der Betriebswirtschaft, 14th edition, Stuttgart, Verlag Schäffer-Poeschel 2009 Wöhe, G.: Einführung in die Allgemeine Betriebswirtschaftslehre, 24th revised edition, Munich, Verlag Vahlen, 2010

Module name	**Digital Technology**
Abbrev.	Dt
Format / SWH	Seminar-type lectures (2 SWH), exercise (1 SWH), practical course (1 SWH) / 4 SWH
Credit points	4 ECTS
Work requirement	In-class time: 60 hrs, self-study: 60 hrs.
Semester	3
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Matthias Mörz
Instructor(s)	Dr. Matthias Mörz
Language	German
Use in other academic programs	AU, EL and EN
Admission requirements	Eligibility to advance pursuant to §6 Para. 1 SPO
Prerequisites	Foundations of electrical and computer engineering, foundations of digital technology
Qualification objectives / skills	After the course students will be able to: • Securely describe the structure, function, and behavior of digital basic circuits and standard switching networks. • Use an oscilloscope and a logic analyzer to analyze logic circuits. • Describe and evaluate different types of memory and programmable logic devices. • Use a method for encoding signals. • Set up and evaluate different computation units. • Analyze and set up counter and frequency divider circuits. • Safely apply automata theory, state graphs, and circuit design methods. • Systematically design switching networks, switching circuits, and state machines and set them up in hardware.

Course contents	• Design of basic digital circuits • Logic gates and FlipFlops • Logic levels and I/O standards • Gate running times and gate transition times • Emergence of hazards and their prevention • Standard switching networks: multiplexer/demultiplexer, encoder/decoder, comparators, adders, subtractors, multipliers, ALU • Feedback switching networks and FlipFlops • Asynchronous and synchronous counters, frequency dividers • Design of the logic analyzer • Measurement and analysis of digital signals with the oscilloscope and the logic analyzer • Design of programmable logic devices: PLD, CPLD, FPGA • Design of memory blocks: ROM, EEPROM, Flash EPROM, SRAM, DRAM, SDRAM • Introduction to automata theory • Design of state machines with state sequence table and state graph • Foundations of coding • Applications of line codes • Foundations of source and channel coding: data compression, detection and correction of transmission errors
Study / examination grades contributing to final grade	Written partial examination (90 minutes)
Other performance tests	None
Media:	Projector and blackboard/whiteboard, electronic scripts and working documents, calculation and simulation programs
Literature:	Beuth Klaus, Digitaltechnik – Elektronik 4, Vogel-Verlag Reichardt Jürgen, Lehrbuch Digitaltechnik, Oldenbourg-Verlag Fricke Klaus, Digitaltechnik, Vieweg-Verlag Dankmeier Wilfried, Grundkurs Codierung, Vieweg-Verlag

Module name	**Electrical Drives and Networks as Introduction to Power Engineering and Renewable Energies**
Abbrev.	EANz
Format / SWH	Seminar-type lectures (2 SWH), exercise (1 SWH), practical course (1 SWH) / 4 SWH
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Semester	3
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Omid Forati Kashani
Instructor(s)	Dr. Omid Forati Kashani, Dr. Michael Rossner
Language	German
Use in other academic programs	AU, EL and EN
Admission requirements	Eligibility to advance pursuant to §6 Para. 1 SPO
Prerequisites	Knowledge of complex AC calculus, pointer diagrams, basic knowledge of magnetic field circuits and couplings and electronic components, basic knowledge of relationships of mechanical quantities.
Qualification objectives / skills	Students will be able to explain the basic principles and operation of DC machines and converters for DC machines. They will be able to explain and understand the three-phase system and the structure, mode of action, and operating behavior of three-phase transformers, as well as three-phase asynchronous and synchronous machines. They will be able to draw and apply various characteristic curves and time histories of the above components. They will be able to analyze simple electromechanical tasks based on learned operating characteristics of the above-mentioned components and to calculate electrical and mechanical quantities for steady-state operating conditions. In the subfield of networks, students will learn the basic principles of electrical power transmission and power considerations in three-phase networks. They will know the advantages and disadvantages of different network forms and their safety aspects, and will be familiar with calculation procedures

	for short-circuit currents, voltage drops, and dimensioning of cables.
Course contents	• Direct current machine Structure and mode of operation, armature winding of a DC machine, air gap fields and operating behavior, voltage generation and torque, types of DC machines, characteristics and control of DC machines, no-load characteristic, speed-torque characteristic, procedure for changing speed, structure and mode of operation of power converters for drives with a DC machine such as buck converter, boost converter, DC converter (four-quadrant converter). • Three-phase system Rotatory voltage generation, generation of three-phase current (three-phase system), star and delta connection, three-phase power, power factor. • Three-phase transformer Construction and operation, types of construction, losses and efficiency, operating behavior, voltage equations and equivalent circuit, no-load operation and magnetization, transformer load, transformer short-circuit, vector groups. • Three-phase asynchronous machine Generation of rotating magnetic fields, spatially offset windings, structure and mode of operation of the asynchronous machine, voltage equations and equivalent circuit, power balance, speed or slip torque characteristic, speed control of asynchronous machine, operating range of the three-phase asynchronous machine, starting, special designs of the cage rotor. • Three-phase synchronous machine Structure and operation, equivalent circuit and vector diagram of solid pole machine, stationary island and mains operation of solid pole machine, V-curves of solid pole machine, torque and stability of solid pole machine, structure and special features of salient pole machine, torque and stability of leg pole machine. • Subfield Networks Forms of energy transmission (direct current, alternating current, three-phase current), power and power measurement in the three-phase current network. Short circuit calculation (symmetrical and simple cases of asymmetrical SC). Network forms (TN, TT, IT), fuse elements, protection regulations. Structure of cables, types of installation, voltage drop calculations.

Module name	**Electrical Engineering**
Abbrev.	Emab
Format / SWH	Seminar-type lectures (3 SWH), seminar paper (1 SWH)
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Semester	6
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Matthäus Brela
Instructor(s)	Dr. Matthäus Brela
Language	German
Use in other academic programs	AU, EL, EN and mechanical engineering
Admission requirements	None
Prerequisites	Basic knowledge of electrical drive technology
Qualification objectives / skills	Subject-related skills • Understanding the operation and structure of electrical machines • Naming and evaluating the steps involved in the manufacture of electrical machines • Reproducing the manufacturing processes necessary for the production • Analyzing, evaluating and developing the manufacturing chain of electrical machines holistically.
Course contents	• Typical applications / fields of application of electrical machinery manufacturing • Electromagnetic and mechanical fundamentals of electrical machines • Basic motor topologies • Components of the drive train • Manufacturing processes for electrical steel strip, electrical single sheet and sheet stack as well as production-related influencing factors • Fundamentals of loss effects and numerical analysis methods

	• Production of hard magnetic materials as well as quality assurance and failure analysis • Magnetization and magnet assembly • Winding technology, impregnation, and insulation • Manufacturing of power electronics • Assembly processes and testing technology for quality assurance at the end of the value chain • Electromagnetic actuators, their manufacturing processes, and quality assurance • Recycling of electrical machines and their components • Traceability and I4.0 in electrical engineering • Basics of contactless power transmission and inductive charging systems • Additive manufacturing in electrical engineering • Superconductor electric motors and transfer systems
Study / examination grades contributing to final grade	Written exam 60 min. and seminar paper (weighting 3:1)
Other performance tests	None
Media:	Projector and blackboard/whiteboard, simulation programs, electronic scripts and working documents, practical exercises.
Literature:	Elektrische Servoantriebe, Manfred Schulze, 2008, ISBN 978-3-446-41459-4 Elektrische Antriebssysteme, Ulrich Riefenstahl, 2nd ed., 2006, ISBN 3-8351-0029-7 Elektrische Maschinen, Hans-Ulrich Giersch, 2003, ISBN 3-519-46821-2

Module name	**Electronics 1 (Part 1)**
Abbrev.	El1A
Format / SWH	Seminar-type lectures with integrated exercises (3 SWH), practical course (1 SWH) / 4 SWH
Credit points	4 ECTS
Work requirement	In-class time: 60 hrs, self-study: 60 hrs.
Semester	2
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Alexander Stadler
Instructor(s)	Dr. Alexander Stadler
Language	German
Use in other academic programs	AU, EL and EN
Admission requirements	None
Prerequisites	Foundations of Electrical Engineering 1, Mathematics 1
Qualification objectives / skills	Subject-related skills: After completing this course, students will be able to: • Understand the conduction mechanisms and basic structures in semiconductors. • Calculate important properties of semiconductor devices. • Work with the characteristic curves of semiconductor devices. • Build and analyze basic circuits with the semiconductor devices. Methodological skills: After completing this course, students will be able to apply the interdisciplinary physical and electrical engineering principles specifically to analyze the conduction mechanisms in electronic devices. They will understand the design of practical circuits and be able to determine the essential functional parameters using both simulation and laboratory measurements. For specialization and better understanding,

	some important semiconductor components are investigated by measurements in the practical course part.
Course contents	• Introduction (electronics and electronic components, conceptual classification, delimitation and subdivision, historical development, economic significance, social significance) • Physical basics of semiconductor electronics (charge carriers in semiconductors, pn-junction and diode, metal-semiconductor junctions, MOS structure) • Semiconductor diodes (working with characteristics, rectifier diode, switching diode, Z-diode, varactor diodes, Schottky diode, tunnel diode, microwave diodes, photodiode, solar cell, light emitting diode and laser diode) • Transistors (bipolar transistor, field effect transistors, special transistors) • Thyristors (structure and operation, electrical properties, special forms - GTO, TRIAC, DIAC) • Operational amplifiers (characteristics, principle of negative feedback, basic circuits, internal construction, offset compensation, frequency response and frequency response correction, slew rate)
Study / examination grades contributing to final grade	Written part examination 90 min. and practical training research paper
Other performance tests	None
Media:	Blackboard, projector, whiteboard, printed lecture notes with exercises, electronically provided accompanying material
Literature:	E. Böhmer, Elemente der Elektronik – Repetitorium und Prüfungstrainer: Ein Arbeitsbuch mit Schaltungs- und Berechnungsbeispielen, Vieweg+Teubner Verlag, 6th completely revised and expanded edition, 2005, ISBN-10: 352854189X E. Böhmer, D. Ehrhardt, W. Oberschelp, Elemente der angewandten Elektronik: Kompendium für Ausbildung und Beruf, Vieweg+Teubner Verlag, 15th updated and expanded edition, 2007, ISBN-10: 3834801240 H. Göbel, Einführung in die Halbleiter-Schaltungstechnik, Verlag Springer Vieweg, 5th updated edition, 2014, ISBN-10: 3642538681 H. Göbel, H. Siemund, Übungsaufgaben zur Halbleiter-Schaltungstechnik, Verlag Springer Vieweg, 3rd edition, 2014, ISBN-10: 3642539025

	S. Goßner, Grundlagen der Elektronik – Halbleiter, Bauelemente und Schaltungen, Shaker-Verlag, 8th updated edition, 2011, ISBN-10: 3826588258 R. Müller, Bauelemente der Halbleiter-Elektronik, Springer-Verlag, 4th revised edition, 1991, ISBN-10: 3540544895 R. Müller, Grundlagen der Halbleiter-Elektronik, Springer-Verlag, 7th corrected edition, 2008, ISBN-10: 3540589120 M. Reisch, Elektronische Bauelemente: Funktion, Grundschaltungen, Modellierung mit SPICE, Springer-Verlag, 2nd edition, 2006, ISBN-10: 3540340149 M. Reisch, Halbleiter-Bauelemente, Springer-Verlag, 2nd revised edition, 2007, ISBN-10: 3540731997 F. Thuselt, Physik der Halbleiterbauelemente: Einführendes Lehrbuch für Ingenieure und Physiker, Springer-Verlag, 2nd edition, 2011, ISBN-10: 3642200311 U. Tietze, C. Schenk, Halbleiter-Schaltungstechnik, Springer-Verlag, 12th edition, 2002, ISBN-10: 3540428496

Module name	**Electronics 1 (Part 2)**
Abbrev.	El1B
Format / SWH	Seminar-type lectures with exercises (3 SWH) and practical course (1 SWH) / 4 SWH
Credit points	4 ECTS
Work requirement	60 hrs. in-class 90 hrs. self-study
Semester	3
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Alexander Stadler
Instructor(s)	Dr. Alexander Stadler Dr. Hans-Martin Tröger Dr. Christian Weindl
Language	German
Use in other academic programs	AU, EL and EN
Admission requirements	Eligibility to advance pursuant to §6 Para. 1 SPO
Prerequisites	Foundations of electrical engineering, measurement technology, and electronics, GE 1, Mathematics 1, Programming 1
Qualification objectives / skills	Students will learn the basic applications of electronic components in amplifier and switch applications. They will learn to synthesize and dimension larger electronic circuits from simple basic elements. In the practical part, they will learn the practical implementation, metrological verification and simulation of the circuits.
Course contents	Characteristics and equivalent circuits of diodes and transistors Basic circuits of semiconductor electronics: Voltage and current sources, small signal amplifiers, DC amplifiers, differential amplifiers with bipolar transistors, and FETs Power amplifiers and power switches Operational amplifiers and their applications

	Linear and clocked power supplies
Study / examination grades contributing to final grade	Written exam (90 min), practical performance test (4 experiments with elaborations), practical course final exam
Other performance tests	None
Media:	Blackboard, overhead/projector Electronically and in paper form provided working documents and exercises, experimental instructions for the practical part of the course Freeware programs such as LTSpice, QucsStudio or TI FilterPro
Literature:	Tietze-Schenk: Halbleiter-Schaltungstechnik, Springer-Verlag, 14th edition 2012 Horowitz-Hill: The Art of Electronics, Cambridge University Press, 3rd edition 2015 Robert A. Pease: Troubleshooting Analog Circuits, Newnes 1993

Module name	**English 1 (GER B2)**
Abbrev.	Eng1
Format / SWH	Seminar-type lectures with exercises / 2 SWH
Credit points	2.5 ECTS
Work requirement	In-class time: 30 hrs, self-study: 45 hrs.
Semester	1
Schedule	Annually
Duration of module	Single semester
Module coordinator	B. Craven, M.A.
Instructor(s)	B. Craven, M.A. / R. Fry, MCLFS
Language	English
Use in other academic programs	AU, EL and EN
Admission requirements	None
Prerequisites	Recommended: Preliminary knowledge of target language GER B1
Qualification objectives / skills	Subject-related skills • Advanced active and passive language skills (speaking, writing, listening comprehension, reading) at least at language competence level B2 • Specialist focus: technical vocabulary, correspondence • Job-specific focus: interviewing, job interviews Methodological competence • Acquisition of learning strategies that enable autonomous learning; certain tasks enable reflection on the employed strategies Intercultural competence • Use of the appropriate language (e.g. registers, courtesies) in intercultural interactions in professional and social situations • Knowledge of English-speaking countries Learning competence

	• Self-learning skills reinforced by the *blended learning* concept
Course contents	• Changing technical topics (e.g. robotics, circuit systems, environmental technology, renewable energies) • Professional correspondence: emails, formal correspondence • Technical writing: reporting, process flow • Application process: curriculum vitae, letter of application, job interview
Study / examination grades contributing to final grade	Other written partial examination 60 min.
Other performance tests	None
Media:	Projector, blackboard, visualizer
Literature:	Script

Module name	**English 2 (GER B2)**
Abbrev.	Eng2
Format / SWH	Seminar-type lectures with exercises / 2 SWH
Credit points	2.5 ECTS
Work requirement	In-class time: 30 hrs, self-study: 45 hrs.
Semester	2
Schedule	Annually
Duration of module	Single semester
Module coordinator	B. Craven, M.A.
Instructor(s)	B. Craven, M.A. / R. Fry, MCLFS
Language	English
Use in other academic programs	AU, EL and EN
Admission requirements	None
Prerequisites	Recommended: Preliminary knowledge of target language GER B1
Qualification objectives / skills	Subject-related skills • Advanced active and passive language skills (speaking, writing, listening comprehension, reading) at least at language competence level B2 • Specialist focus: technical vocabulary, correspondence • Job-specific focus: interviewing, job interviews Methodological competence • Acquisition of learning strategies that enable autonomous learning; certain tasks enable reflection on the employed strategies Intercultural competence • Use of the appropriate language (e.g. registers, courtesies) in intercultural interactions in professional and social situations • Knowledge of English-speaking countries Learning competence • Self-learning skills reinforced by the *blended learning* concept

Course contents	• Changing technical topics (e.g. robotics, circuit systems, environmental technology, renewable energies) • Professional correspondence: emails, formal correspondence • Technical writing: reporting, process flow • Application process: curriculum vitae, letter of application, job interview
Study / examination grades contributing to final grade	Other written partial examination 60 min.
Other performance tests	None
Media:	Projector, blackboard, visualizer
Literature:	Script

Module name	**Foundations of Electrical Engineering 1**
Abbrev.	GE1
Format / SWH	Seminar-type lectures (6 SWH), exercise (2 SWH) / 8 SWH
Credit points	8 ECTS
Work requirement	In-class time: 120 hrs, self-study: 120 hrs.
Semester	1
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Bernd Hüttl
Instructor(s)	Dr. Bernd Hüttl, Dr. Michael Rossner
Language	German
Use in other academic programs	AU, EL and EN
Admission requirements	None
Prerequisites	Mastery of geometry and algebra and systems of linear equations; knowledge of integral, differential, and vector calculus; basic knowledge of physics at *Abitur* level.
Qualification objectives / skills	Technical-methodical competences • Students will master the basic physical quantities for describing electrical networks, as well as electric and magnetic fields. • They will understand the basic equations describing electric and magnetic fields and can calculate fields of simple geometries. • They will know Maxwell's equations in vector analytical representation and understand their meaning. • They will recognize the importance of these fundamentals for the design of electrical equipment and circuits and be able to perform calculations yourself using simple examples. • They will learn the structure of simple DC networks and master the basic rules of network calculation. • Based on this, they will be able to apply generally applicable calculation methods for more complex direct current circuits and

	to analyze and calculate transient processes in linear networks with an energy storage device.
Course contents	• **Electric field** Clarification of terms: charge, field strength, voltage, potential, and capacitance. Calculation of electrostatic fields and potential fields for simple geometries. Matter in electric field and polarization; energy and forces in electric field. Fields of stratified arrangements. Electric flow field. • **Magnetic field** The static magnetic field in vacuum: magnetic phenomena, Lorentz force and magnetic flux density, Ampere's circuit law and magnetic field strength. The magnetic field in matter: paramagnetism, diamagnetism and ferromagnetism. Permeability. Simple magnetic circuits. Electromagnetic voltage generation: Motion and rest induction, self-induction, and self-inductance. Mutual induction and mutual inductance. Energy and forces in the magnetic field. • **Linear DC networks** The DC electric circuit: Ohm's law, mesh and node rule, voltage and current divider. Ideal and real voltage and current sources: Source conversion, matching and power balance. Network calculation methods: Star-delta conversion, equivalent source method, superposition method, mesh current and node potential method. Controlled sources in four-pole representation. • **Switching operations in linear networks** Classes and terminal behavior of linear two-terminal systems. Approach and solution of differential equations for the calculation of switching on and off processes in ohmic-inductive or ohmic-capacitive networks. Periodic switching.
Study / examination grades contributing to final grade	Written partial examination (150 minutes)
Other performance tests	None
Media:	Projector and blackboard/whiteboard, electronic scripts and working documents, and practice exercises.
Literature:	A. Führer, K. Heidemann, W. Nerreter: Grundgebiete der Elektrotechnik, Carl Hanser Verlag R. Paul: Elektrotechnik Vol. I, Springer Verlag

	W.-E. Büttner: Grundlagen der Elektrotechnik I, Oldenbourg Verlag M. Albach: Grundlagen der Elektrotechnik 1 und 2, Pearson Studium

Module name	**Foundations of Electrical Engineering 2**
Abbrev.	GE2
Format / SWH	Seminar-type lectures / 4 SWH
Credit points	4 ECTS
Work requirement	In-class time: 60 hrs. self-study: 60 hrs.
Semester	2
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Bernd Hüttl
Instructor(s)	Dr. Bernd Hüttl
Language	German
Use in other academic programs	AU, EL and EN
Admission requirements	None
Prerequisites	Knowledge of complex calculus, basic understanding of electric and magnetic fields, calculation methods for linear networks.
Qualification objectives / skills	Subject-related skills After the course, students will be able to: • Apply the knowledge and skills acquired in the first semester to the analysis of direct current networks. Extend their knowledge to linear AC networks in steady state using the complex AC calculus. • Recognize important AC electrical network configurations, name their practical significance, and analyze and calculate such network configurations. • Represent and calculate the interrelationships of the transformer in steady state operation. These skills are based on an electrical equivalent circuit and an understanding of the operating characteristics under different operating conditions and load characteristics.
Course contents	• **AC power systems** Description of stationary sinusoidal oscillations by complex rms values, passive linear two-terminal circuits in description as complex resistances and conductances,

	simple LRC circuits (series and parallel connection), branched circuits, oscillating circuits and transformation quadrupoles, application of locus curves, bode diagrams, four-pole coefficients and calculation methods for the analysis of complex networks. • **AC transformer** Description of the ideal transformer, consideration and calculation of losses and dispersion in the transformer, real single-phase transformers in steady-state operation: equivalent circuit, pointer diagram. Simplified considerations in open circuit and short circuit. Operating behavior in nominal operation with resistive, resistive-inductive and resistive-capacitive load.
Study / examination grades contributing to final grade	Written partial examination (90 minutes)
Other performance tests	None
Media:	Blackboard, projector, Moodle platform Handouts and exercises provided in electronic format
Literature:	A. Führer, K. Heidemann, W. Nerreter: Grundgebiete der Elektrotechnik, Vol. 2, Hanser Verlag S. Altmann, D. Schlayer: Lehr- und Übungsbuch Elektrotechnik, Hanser Verlag R. Ose: Elektrotechnik für Ingenieure, Hanser Verlag

Module name	**Mathematics 1**
Abbrev.	Mth1
Format / SWH	Seminar-type lectures, integrated exercises / 8 SWH
Credit points	8 ECTS
Work requirement	In-class time: 120 hrs. self-study: 120 hrs.
Semester	1
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Bernd Hüttl
Instructor(s)	Dr. Bernd Hüttl and Dr. Rainer Dohlus
Language	German
Use in other academic programs	AU, EL and EN
Admission requirements	None
Prerequisites	None
Qualification objectives / skills	After the course students will be able to: **concerning technical skills** - Understand basic mathematical thinking and concepts. - Apply mathematical procedures and techniques. **concerning methodological skills** - Mathematically understand and solve physics/engineering problems
Course contents	**Foundations:** Logic, algebra of sets, real and complex numbers, equations and inequalities, functions and curves. **Linear Algebra:** Vectors, matrices, determinants, and systems of equations. **Limits**: Sequences and series **Differential and integral calculus** **First order ordinary differential equations**
Study / examination grades contributing to final grade	Written partial examination (120 minutes)

Other performance tests	None
Media:	Oral and written lectures with blackboard and video projector, electronic scripts and workbooks, calculation exercises via Moodle, etc.
Literature:	Papula: Mathematik für Ingenieure I – III Meyberg/Vachenauer: Höhere Mathematik I und II

Module name	**Mathematics 2**
Abbrev.	Mth2
Format / SWH	Seminar-type lectures, integrated exercises / 4 SWH
Credit points	4 ECTS
Work requirement	In-class time: 60 hrs. self-study: 60 hrs.
Semester	2
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Matthäus Brela
Instructor(s)	Dr. Matthäus Brela
Language	German
Use in other academic programs	AU, EL and EN
Admission requirements	None
Prerequisites	Methods and skills of mathematics 1
Qualification objectives / skills	Subject-related skills After the course, students will be able to: • Apply basic mathematical thinking, concepts, and techniques. • Understand, formulate, and solve technical problems mathematically. • Particularly recognize higher order ordinary linear differential equations and systems of differential equations in their properties, develop appropriate solution strategies, and successfully implement them. • Apply the Laplace transform with its specific properties to solve mathematical problems, especially to solve linear ordinary differential equations. • Analyze and represent scalar functions of several variables in behavior and subject these functions to differential and integral operations to solve engineering problems. • Apply basic vector analytic operations to vector fields, especially to perform electrical engineering field calculations.

Course contents	• Higher order ordinary linear differential equations and systems of differential equations: Properties of ordinary linear differential equations, solution concepts for solving homogeneous and inhomogeneous differential equations, fitting solutions to constraints, solving simple systems of differential equations, emphasis on second order differential equations • Laplace transform: Properties of the integral operator and computational concepts for transformations from original to image space and back, application of the Laplace operator to problems of differentiation and integration, application to ordinary differential equations of higher order • Scalar functions of several variables: Representation and analysis (continuity and extrema), calculation of limits, application of differentiation and integration operations • Vector analysis: Introduction, representation and analysis of vector fields, application of differential operators and integrations for simple field calculations
Study / examination grades contributing to final grade	Written partial examination (90 minutes)
Other performance tests	None
Media:	Blackboard, projector, Moodle platform Handouts and exercises provided in electronic format
Literature:	Papula: Mathematik für Ingenieure, Vols 2 und 3 Meyberg/Vachenauer: Höhere Mathematik Vols 1 and 2 Stingl: Mathematik für Fachhochschulen

Module name	**Mathematics 3**
Abbrev.	Mth3
Format / SWH	Seminar-type lectures / 4 SWH
Credit points	4 ECTS
Work requirement	In-class time: 60 hrs, self-study: 60 hrs.
Semester	3
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Martin Springer
Instructor(s)	Dr. Martin Springer
Language	German
Use in other academic programs	AU, EL and EN
Admission requirements	Eligibility to advance pursuant to §6 Para. 1 SPO
Prerequisites	Methods and skills from Mathematics 1 and 2
Qualification objectives / skills	Application of the z-transform to the treatment of difference equations, knowledge and application of the Fourier integral and the discrete Fourier transform, knowledge of basic stochastics, solving problems in combinatorics, application of basic probability distributions
Course contents	The z-transform and its application to difference equations: • Properties • Application to LTI systems The Fourier transform • Fourier series • Fourier integral • Discrete Fourier transform Stochastics • Descriptive statistics

	• Combinatorics • Probability spaces • Distributions
Study / examination grades contributing to final grade	Written partial examination (90 minutes)
Other performance tests	None
Media:	Blackboard Overhead projector PC
Literature:	e.g. L. Papula: Mathematik für Ingenieure. Vieweg + Teubner (div. editions) Burg, K.: Höhere Mathematik für Ingenieure; vol. 3. Vieweg+Teubner, 2009 Butz, T.: Fourier-Transformation für Fußgänger. Vieweg+Teubner, 2009 Oppenheim, A.V., Willsky: Signale und Systeme. VCH, 1992 Bosch, K.: Elementare Einführung in die Wahrscheinlichkeitsrechnung. Vieweg+Teubner, 2010 Henze, N.: Stochastik für Einsteiger. Vieweg+Teubner, 2010

Module name	**Microcomputer Technology**
Abbrev.	MCT
Format / SWH	4 SWH: – Seminar-type lectures (2 SWH) – Exercise (1 SWH) and practical course (1 SWH)
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Semester	3
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Peter Johann Raab
Instructor(s)	Dr. Peter Johann Raab
Language	German
Use in other academic programs	AU, EL and IF
Admission requirements	Eligibility to advance pursuant to §6 Para. 1 SPO
Prerequisites	Foundations of computer science and mathematics
Qualification objectives / skills	**Subject-related skills:** – Recognition of structures and assessment of the properties of hardware and software components of modern microcomputer systems – Development of software for microcomputer systems, incl.: – Machine-oriented programming in assembly – Analysis and implementation of real time properties – Development with the help of asynchronous events (interrupts) – Control of typical input/output devices – Use of modern development and debugging tools **Interdisciplinary skills:** – Teamwork – Analysis and implementation of requirements into a technical realization
Course contents	Foundations: Overview of structure, application areas and requirements of embedded systems, hardware and abstractions, structure of ARM-based microcontrollers

	Programming: Assembler programming, addressing modes, computer arithmetic and loop programming, number systems, arithmetic and logic operations, program structures, subroutines, stack, interrupts, timers and counters, real-time behavior, synchronous and asynchronous software design, high level language reference (embedded C, compiler). Input/output systems: Digital I/O, interfaces, UART, bus systems, access methods, analog signals, and conversion. Practical application: Use of modern development tools (debugging, real-time emulation), configuration of a current practice-oriented system of prefabricated hardware components (e.g. keyboards, LCD displays, GPS receivers, RFID devices, Bluetooth transmitters, transducers, stepper motor control, DCF receivers, printing unit control), application of hardware-related (assembly) programming for a complex application using various hardware components.
Study / examination grades contributing to final grade	Written examination (90 minutes) and prStA (experiments and surveys)
Other performance tests	None
Media	Slides / lecture script / lab use
Literature	Michael Engel, "Maschinennahe Programmierung mit arm Cortex-M-Prozessoren" (in preparation) Joseph Yiu, "The Definitive Guide to ARM Cortex-M3 and Cortex-M4 Processors," Newnes, 3rd edition 2013, ISBN-13: 978-0124080829 Jonathan M. Valvano, "Embedded Systems: Introduction to ARM Cortex-M Microcontrollers," CreateSpace Independent Publishing, 2nd ed. 2012, ISBN-13: 978-1477508992

Module name	**Physics**
Abbrev.	Ph
Format / SWH	Seminar-type lectures (3 SWH), integrated exercise, practical course (1 SWH) / 4 SWH
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Semester	1
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Martin Springer
Instructor(s)	Dr. Martin Springer, Dr. Christian Weindl
Language	German
Use in other academic programs	AU, EL and EN
Admission requirements	None
Prerequisites	Basic mathematical knowledge
Qualification objectives / skills	Subject-related skills After the course, students will be able to: • Theoretically understand physical problems in mechanics and wave physics, develop practical solutions and successfully implement them. • Analyze and quantitatively describe physical and technical problems. Interdisciplinary skills • The acquired knowledge of physics and the developed ability to create solution concepts are understood to be the basis for the advanced courses in electrical engineering. Methodological competence • Students will learn to understand experiments as projects with tasks ranging from independent planning and execution to achieving results and assessing accuracy.

	Social competence • Working in project groups while performing experiments develops the ability to solve problems in a team.
Course contents	• Measurement techniques: Measurement of physical quantities, error determination of measurements and measurement series, error propagation law, and regression analysis • Mechanics: Kinematics and dynamics of mass points, dynamics of reference systems, mechanical energy and momentum, conservation laws, mechanical collisions, mechanical oscillations and waves, and their superpositions • Wave optics: Mathematical description of optical waves and of wave packets, diffraction, interference and coherence of optical waves, dispersion and refraction law of waves, and optical radiation sources
Study / examination grades contributing to final grade	Written examination 90 min. and practical performance tests
Other performance tests	None
Media:	Blackboard, projector, Moodle platform Handouts and exercises provided in electronic format
Literature:	Hering/Martin/Stohrer: Physik für Ingenieure, Springer Verlag, Berlin 2012, 11th edition Gerthsen: Physik, Springer Verlag, Berlin 2010, 24th edition

Module name	**Programming 1**
Abbrev.	Prg1
Format / SWH	Seminar-type lectures (2 SWH), exercise (2 SWH) / 4 SWH
Credit points	4 ECTS
Work requirement	In-class time: 60 hrs. self-study: 60 hrs.
Semester	1
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Wolfram Haupt
Instructor(s)	Dr. Wolfram Haupt
Language	German
Use in other academic programs	AU, EL and EN
Admission requirements	None
Prerequisites	None
Qualification objectives / skills	Students will be able to classify computer science and programming in the field of electrical engineering. In addition, they will know basic terms that are required for communication in the field of computer science. They will also be familiar with the basic structure of a computer and how it works in principle. Students will be able to handle important number systems and also convert them. Furthermore, students will be able to create their own small programs to solve textually described problems using algorithms. Students will use different elements for the flow control of a program and be able to use them for the solution.
Course contents	Theory: • Programming in electrical engineering - Why? • Structure of a computer • How a computer works • Number system - bits & bytes • How does a compiler or interpreter work? Practice: • Programs - what are they used for? • What are algorithms?

	• Basic elements of Python • Debugging or dealing with errors • Turtle graphics • Python modules • Functions • Conditions • More about iteration • Strings • Lists • Files • NumPy + Matplotlib
Study / examination grades contributing to final grade	Written partial examination (90 minutes)
Other performance tests	None
Media:	Common presentation techniques, books, script and presentation slides as well as exercises (partly with solutions) on the intranet. Further use of an eLearning platform. Additional use of hardware in the exercises.
Literature:	Interactive script additionally: Allen B. Downey, Think Python

Module name	**Programming 2**
Abbrev.	Prg2
Format / SWH	Seminar-type lectures (2 SWH), PC / project exercises (2 SWH) / 4 SWH
Credit points	4 ECTS
Work requirement	In-class time: 60 hrs, self-study: 60 hrs.
Semester	2
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Christian Weindl
Instructor(s)	Dr. Christian Weindl
Language	German
Use in other academic programs	AU, EL and EN
Admission requirements	None
Prerequisites	• Basic knowledge of imperative programming • Basics of using an integrated development environment (IDE) • Handling binary numbers • Basics of Boolean algebra
Qualification objectives / skills	Subject-related and methodological skills: Students will be able to: • Classify tasks and program solutions in the field of electrical engineering. • Handle and convert important number systems. • Create their own, smaller programs to solve textually described problems using algorithms. • Create and maintain programs with readable and maintainable source code. • Use different elements for the flow control of a program and use these for the solution. • Understand and apply known algorithms from different application areas. • Understand suitable data structures and techniques for algorithm design and apply them to non-trivial problems. • Know, understand, and apply algorithm analysis with respect to complexity, memory requirements, etc.

Course contents	• Programming tasks in electrical engineering • Number systems - bits & bytes • Function of interpreters and compilers • Selected software engineering techniques - Encapsulation and modularity • File access in C • Recursion and iteration • Dynamic memory management • Algorithms: e.g. searching, sorting, etc. • Data structures: Stacks, lists, queues, trees, etc. • Comparison: C and C++ • Insight into advanced programming techniques: GUIs, object orientation, etc.
Study / examination grades contributing to final grade	Written partial examination (90 minutes)
Other performance tests	None
Media:	Projector, presentation slides, blackboard, whiteboard, exercises in electronic form (some with solutions). If necessary, use of an e-learning system. Additional use of hardware in the exercises.
Literature:	Ottmannn/Widmayer: Algorithmen und Datenstrukturen, 5th edition, Spektrum Akademischer Verlag, 2012 Saake/Sattler: Algorithmen und Datenstrukturen, dpunkt.verlag, 2014 Robert C. Martin, "Clean Code", Prentice Hall, 2009 Collins-Sussman/Fitzpatrick/Pilato, Version Control with Subversion, http://svnbook.red-bean.com/index.de.html Additional C literature: Internet documents and literature in reading room

Module name	**Signals and Systems as an Introduction to Electrical Engineering and Information**
Abbrev.	SuS
Format / SWH	Seminar-type lectures (3 SWH), exercise (1 SWH) / 4 SWH
Credit points	4 ECTS
Work requirement	In-class time: 60 hrs, self-study: 60 hrs.
Semester	3
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Matthias Mörz
Instructor(s)	Dr. Matthias Mörz
Language	German
Use in other academic programs	AU, EL and EN
Admission requirements	Eligibility to advance pursuant to §6 Para. 1 SPO
Prerequisites	Foundations of electrical engineering, electronic components, circuit technology
Qualification objectives / skills	After the course students will be able to: • Explain and evaluate the basic properties of signals and systems. • Describe and calculate linear time-invariant (LTI) systems in their continuous-time representation (linear differential equations, convolution operation, convolution integral). • Describe and calculate continuous LTI systems in the frequency domain (Fourier transform). • Describe and calculate continuous LTI system in the image domain (Laplace transform). • Explain the sampling operation with its meaning in the time and frequency domain. • Describe and calculate linear time invariant (LTI) systems in their discrete time representation (z-transform).
Course contents	• Transition to normalized signals • Continuous-time elementary signals • Linear time invariant (LTI) systems - continuous time • System description with linear differential equations • Impulse, step and ramp response of LTI systems

	• Convolution operation • System description with the help of Laplace transforms • Transfer function • Block diagram algebra • Frequency response and Bode diagram • Frequency response of elementary systems (P,I,D,PT1,PD,DT1) • Linear time invariant (LTI) systems - discrete time • Sampling (time and frequency domain) • Elementary (discrete-time) signal sequences • Step and impulse response • Convolution • Z-transform
Study / examination grades contributing to final grade	Written examination 90 min.
Other performance tests	None
Media:	Projector and blackboard/whiteboard, electronic scripts and working documents, calculation programs
Literature:	Scheithauer Rainer, Signale und Systeme, Teubner-Verlag Werner Martin, Signale und Systeme, Vieweg+Teubner-Verlag

Module name	**Control Technology as an introduction to automation technology and robotics**
Abbrev.	StRt
Format / SWH	Seminar-type lectures (3 SWH), practical course (1 SWH) / 4 SWH
Credit points	4 ECTS
Work requirement	In-class program: 60 hrs. self-study: 60 hrs.
Semester	3
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Matthäus Brela
Instructor(s)	Dr. Matthäus Brela
Language	German
Use in other academic programs	AU, EL and EN
Admission requirements	Eligibility to advance pursuant to §6 Para. 1 SPO
Prerequisites	Foundations of electrical circuitry and engineering mechanics. Linear differential equations.
Qualification objectives / skills	• Students will: Know the difference between control and regulation. • Know the basic principle of discrete-event controls and be able to apply their modeling to simple examples of automation technology. • Know selected standards of programmable logic controllers and programming languages, and be able to create simple control programs. • Know the difference between analog, digital, and binary signals and be able to process them in terms of control technology. • Know the basic technical structure of control, regulation and automation systems. • Understand the basic principle of the feedback control loop and its breakdown into different function blocks. • Be familiar with the concept of control systems and be able to mathematically model simple dynamic systems in

	electrical engineering, mechanics and process engineering. • Be familiar with the most important controller types, be able to analyze their influence on the system behavior, and know application areas as well as design methods by means of selected setting rules for the controller parameters. • Be able to design, program, and test the basic controllers in software.
Course contents	• **Control technology** Discrete event control, programming according to IEC61131-3 in the languages ST, FBD, LD, IL, reading sensor data, processing control data, and setting actuators. • **Technology of control, feedback control and automation systems** Basic system structure and components, memory functions, edge evaluation, time functions, clock signals, counting functions, and other basic links. Programming of transfer functions. • **Basic structure of the standard control loop** Controller, controlled system, actuators and sensors, reference, controlled, manipulated, and disturbance variables. Representation of a control loop as block structure, differential equation, transfer function. • **Controlled systems** Proportional and integrating controlled systems with and without time delay constants, dead time element, description by linear differential equations, and determination of the system parameters from the step response. • **Control** Important controller types, their characteristic values and application, control and disturbance behavior, and adjustment rules for optimizing the control loop behavior. • **Practical course:** Acquisition of sensor signals, introduction to motion control, interaction of controller and draw frame.
Study / examination grades contributing to final grade	Written examination 90 min. and practical performance tests
Other performance tests	None
Media:	Blackboard, overhead/projector

	Electronically provided working documents and exercises Computer-aided development and simulation environments
Literature:	H. Unbehauen: Regelungstechnik I: Klassische Verfahren zur Analyse und Synthese linearer kontinuierlicher Regelsysteme, Fuzzy-Regelsysteme, Vieweg Verlag J. Kahlert: Crash-Kurs Regelungstechnik, VDE Verlag GmbH W. Schneider: Praktische Regelungstechnik, Vieweg+Teubner Verlag F. Tröster: Steuerungs- und Regelungstechnik für Ingenieure, Oldenbourg Wissenschaftsverlag

Module name	**Computer Engineering**
Abbrev.	TI
Format / SWH	Seminar-type lectures (3 SWH), exercise (1 SWH) / 4 SWH
Credit points	4 ECTS
Work requirement	In-class time: 60 hrs, self-study: 60 hrs.
Semester	2
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Matthias Mörz
Instructor(s)	Dr. Matthias Mörz
Language	German
Use in other academic programs	AU, EL and EN
Admission requirements	None
Prerequisites	Foundation of electrical engineering and computer science
Qualification objectives / skills	After the course students will be able to: • Deal confidently with logic operations and the calculation and simplification rules of circuit algebra. • Analyze logic circuits. • Simplify logic operations with the Karnaugh-Veitch diagram and according to Quine & McCluskey. • Develop and build logic circuits. • Explain the essential differences in the use of different circuit families in circuit realization and take them into account in circuit construction. • Build and evaluate simple arithmetic circuits. • Analyze and build time-dependent binary circuits (counters, frequency dividers).
Course contents	• Logical operations • Boolean algebra, circuit algebra • Basic functions and composite elements • Circuit analysis • Construction of logic circuits with different circuit families • Circuit synthesis • Normal forms (DNF, KNF)

	• Minimization methods: Karnaugh-Veitch / KV diagram, Quine McCluskey • Binary codes • Combinatorial logic functions / standard circuit networks: encoder, decoder, multiplexer, comparator, adder, subtractor • Time-dependent binary circuits, counters, and frequency dividers
Study / examination grades contributing to final grade	Written partial examination (90 minutes)
Other performance tests	None
Media:	Projector and blackboard/whiteboard, electronic scripts and working documents, calculation and simulation programs
Literature:	Beuth, Digitaltechnik – Elektronik 4, Vogel-Verlag Schiffmann, Schmitz: Technische Informatik 1, Springer-Verlag Becker, Drechsler, Molitor: Technische Informatik, Pearson-Verlag

2. Required Internship Semester

Module name	**Internship Course**
Abbrev.	PxLv
Format / SWH	Seminar-type lectures, practical course, project work / 4 SWH
Credit points	5 ECTS
Work requirement	In-class time 60 hrs, self-study 90 hrs.
Semester	4
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Matthias Mörz
Instructor(s)	Various lecturers and adjunct professors
Language	German
Use in other academic programs	AU, EL and EN
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	None
Qualification objectives / skills	• Students will know and reflect on selected topics with particular relevance for the tasks in the required internship. • They will develop and perfect techniques, skills and soft skills that are highly relevant for a job in a company. • They will cultivate the exchange of experience with professional colleagues and recognize the benefits of networking.
Course contents	As specified in the study and examination plan
Study / examination grades contributing to final grade	None
Other performance tests	Practical performance and participation certificates
Media:	
Literature:	

Module name	**Practical Training Seminar**
Abbrev.	Pxsem
Format / SWH	Seminar / 2 SWH
Credit points	2 ECTS
Work requirement	In-class time: 30 hrs, self-study: 30 hrs.
Semester	4
Module coordinator	Dr. Matthias Mörz
Instructor(s)	Dr. Matthias Mörz
Language	German
Use in other academic programs	AU, EL and EN
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	None
Qualification objectives / skills	• Students will be able to present a self-worked task corresponding to their field of study in writing and orally in an appropriate form. • They will know basic rules for writing academic/scientific papers and be able to apply them independently. • They will further develop their ability to present subject-specific content in front of an expert audience.
Course contents	Depending on the tasks worked on during the required internship.
Study / examination grades contributing to final grade	None
Other performance tests	Written practical report (approx. 20 pages), oral, media-supported presentation (approx. 15 minutes)
Media:	Projector / if needed: blackboard or Whiteboard
Literature:	

3. Specialization Program

3.1 Compulsory Modules

Module name	**Electrical Drive and Converter Technology**
Abbrev.	EAS
Format / SWH	Seminar-type lectures (2 SWH), exercise (1 SWH), practical course (1 SWH) / 4 SWH
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Semester	5
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Omid Forati Kashani
Instructor(s)	Dr. Omid Forati Kashani
Language	German
Use in other academic programs	AU, EN, EL
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	Previous knowledge of structure, mode of operation and various characteristics of DC, asynchronous and synchronous machines from the subject "Electrical Drives and Networks".
Qualification objectives / skills	Students will: Be able to apply the solution methods in drive engineering and explain the mode of operation of the converter topologies as rectifier, inverter and DC converter for the DC as well as three-phase systems. Be able to analyze and solve drive engineering problems in theory and practice and to predict the behavior of the drives with the above-mentioned components. Understand the basics of the control of electric drives and the associated boundary conditions and be able to apply the basic and fundamental methods.

Course contents	• Mechanical basics (translational and rotational motion, speed converter (gearbox), steady state operation of a drive, and stability condition of an operating point) • Drives with DC machines (review of types of DC machines, operating behavior of DC machines, dynamic operation of DC machines) • Drives with rotating field machines (review about the asynchronous and synchronous machine, operating behavior and control of the ASM and SM) • Special machines (operation of the servo motor, the stepper motor, the switched reluctance machine, the brushless DC machine and the linear motor) • Line-commutated converters (two-pulse bridge circuit, B6 circuit and 12-pulse converter) • Self-controlled power converters (operation and control of DC-DC converters, operation and control of DC-DC converters on the mains and machine side, pulse width modulation, operation and control of DC-DC converters) • Fundamentals of control of electric drives (speed and torque control of DC drives, two-axis theory of three-phase machines and space vector, control of three-phase machines in rotating coordinate system, control of line-side converters, and space vector modulation.
Study / examination grades contributing to final grade	Written examination 90 min. and practical training research paper
Other performance tests	None
Media:	Blackboard, overhead/projector/visualizer/whiteboard Electronically provided working documents and exercises, practical exercises on the test bench in the laboratory
Literature:	- Hans-Christoph Skudelny, Elektrische Antriebe, Verlag der Augustinus Buchhandlung, 1997 - Hans-Christoph Skudelny, Stromrichtertechnik, Verlag der Augustinus Buchhandlung, 1997 - Helmut Späth, Elektrische Maschinen und Stromrichter, Verlag Braun Karlsruhe, 1991 - Rolf Fischer, Elektrische Maschinen, Karl Hanser Verlag Munich, 2011 - Johannes Teigelkötter, Energieeffiziente elektrische Antriebe, Springer Verlag, 2013

Module name	**Electrical Power Storage**
Abbrev.	EEs
Format / SWH	Seminar-type lectures (2 SWH), integrated exercise, practical course (2 SWH) / 4 SWH
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Abbrev.	EEs
Semester	6
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Christian Weindl
Instructor(s)	Dr. Christian Weindl, Dr. Michael Rossner
Language	German
Use in other academic programs	Open to all 3 electrical engineering fields of study
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	Ph, GE1, Math 1 and 2
Qualification objectives / skills	Subject-related skills After the course students will: • Know electric power system fundamentals and grid and market-based storage needs. • Know the application possibilities and benefits of different storage systems. • Be able to calculate the energy content of electrical energy storage systems. • Be able to analyze and compare the storage potentials of different storage systems. • Be able to calculate storage requirements and load balancing in power supply systems. • Be able to analyze, evaluate, and compare economic aspects of the operation of chemical energy storage systems. • Be able to recognize and determine the technical and economic design criteria of energy storage systems that correspond to the requirements. • Be able to perform calculations for the design of storage systems.

	• Understand the basic electrochemical processes in battery storage systems. • Understand the basic electrochemical processes in electrolyser fuel cell systems. • Understand basic measurement procedures for charging and discharging behavior and perform them. • Know procedures for assessing the condition of chemical energy storage systems. • Be able to carry out simple economic feasibility studies and understand payback calculations. Methodological competence After the course, students will be able to classify the properties of different electrical energy storage systems and to select energy storage systems that meet their requirements and dimension them. They will have developed an understanding of the functionality, operation and characteristics of different types of energy storage systems and be able to evaluate their use according to economic and environmental aspects.
Course contents	Flexibilization of the electrical energy supply - renewable energies & storage demand Technical and regulatory framework conditions for the use of storage - Grid services Properties and parameters of different energy storage systems Derivation of an abstract storage model Hydraulic storage systems Electromechanical storage systems Electrostatic storage systems Electrochemical storage systems Hybrid storage systems Evaluation criteria for the use of energy storage systems Comparison and application scenarios of different storage technologies Operation, aging, and economic efficiency of electrical energy storage systems Mode of operation of electrolyser / fuel cell systems Practical course: - Measurement methods - determination of the cell properties of battery storage systems

	- Application and comparison of different charging methods - Determination of the SOC (state of charge) - Derivation of cell models - Design of battery systems - Thermal load and humidity management on a PEM fuel cell - U_I characteristics of a fuel cell - Design of a battery monitoring and management system
Study / examination grades contributing to final grade	Written examination (90 minutes) and practical performance tests
Other performance tests	None
Media:	Blackboard, projector, whiteboard, Moodle platform Handouts and exercises provided in electronic format
Literature:	Michael Sterner, Ingo Stadler: "Energiespeicher - Bedarf, Technologien, Integration", Springer-Verlag, 1st edition 2014 Eckard Fahlbusch (publ.): "Batterien als Energiespeicher", Beuth Verlag GmbH Berlin Wien Zürich, 1st edition 2015 Frank S. Barnes, Jonah G. Levine: "Large Energy Storage Systems Handbook", CRC Press – Taylor and Francis Group 2011 Erich Rummich: "Energiespeicher - Grundlagen, Komponenten, Systeme und Anwendungen", expert-verlag, 2009 Robert Schlögl: "Chemical Energy Storage" Verlag Walter de Gruyter, 2013 Chris Menictas, Maria Skyllas-Kazarcos, Tuti Mariana Lim: "Advances in Batteries for Medium- and Large-Scale Energy Storage”, Woodhead Publishing – Elsevier Ltd., Cambridge, 2015

Module name	**Electrical Power Distribution**
Abbrev.	EEv
Format / SWH	Seminar-type lectures (3 SWH), practical course (1 SWH) / 4 SWH
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Recommended semester	6
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Michael Rossner
Instructor(s)	Dr. Michael Rossner
Language	German
Use in other academic programs	
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	Lecture contents of basic studies, especially basics of electrical engineering, mathematics, and physics
Qualification objectives / skills	- Students will know the structure of power generation and distribution in Germany and Central Europe. - They will be familiar with the boundary conditions and influencing factors of pricing on the electricity market. - Students will be able to independently assess the profitability of investments, especially according to linear and annuistic approaches. - They will know that the steam power plant cycle can be calculated thermodynamically and be familiar with components of the power plant. - They will be able to apply basic dimensioning criteria of transformers, synchronous generators, and switches independently. - They will be able to apply basic principles of voltage and frequency maintenance in the extra-high voltage grid to an example. - They will be able to apply line equations to calculate voltage and current distributions on lines. - They will be able to calculate near-generator and far-generator symmetrical short-circuit currents. - They will be able to apply the calculation of unbalanced short circuits by means of the symmetrical

	components to simple examples. - They will understand the basics of fuse settings (differential, admittance and distance protection). - They will be able to calculate simple examples of load flow calculation.
Course contents	Seminar-type lectures: - Structure of energy supply Germany and Central Europe - Pricing and electricity market - Cost accounting - Steam power process, thermodynamics - Components of power distribution (transformer, generator switch, protection....) - Voltage and frequency maintenance, HVDC - Line-related wave propagation - Operating diagram medium voltage line - Dimensioning of overhead lines and cables - Symmetrical short circuit - Generator short circuit - Unbalanced components - Load flow calculation - Protection devices practical course: - Measurements on line models 220kV and 20kV line simulation - Short circuit test, fuse settings - Synchronization (2-sided feeding)
Study / examination grades contributing to final grade	Written examination 90 min., practical course reports
Other performance tests	
Media:	Blackboard, projector, script
Literature:	K. Heuk; K-D Dettmann, D. Schulz; Elektrische Energieversorgung; Springer-Verlag; 9th ed. 2013 D. Oeding, B.R. Oswald; Elektrische Kraftwerke und Netze; Springer Verlag, 7th ed. 2004 D. Nells; Ch. Tuttas; Elektrische Energietechnik; B.G. Teubner Stuttgart, 1998 Hosemann; Boeck; Grundlagen der elektrischen Energietechnik; Springer-Verlag; 4th ed. 1990 Wolfgang Schluft, Taschenbuch der "Elektrischen Energietechnik" Hanser Verlag 2007 U.Ungrad; W.Winkler; A.Wiszniewski; Schutztechnik in Elektroenergiesystemen; Springer-Verlag, 2nd ed. 1994

Module name	**Electrical Power Conversion**
Abbrev.	EEw
Format / SWH	Seminar-type lectures with integrated exercises (3 SWH), practical course (1 SWH) / 4 SWH
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Semester	5
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr.-Ing. Alexander Stadler
Instructor(s)	Dr.-Ing. Alexander Stadler
Language	German
Use in other academic programs	-
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	Mathematics, foundations of electrical engineering
Qualification objectives / skills	Subject-related skills: After the course students will: • Know the basic power electronic circuits for electrical energy conversion and be able to understand and explain their fundamentals. • Be familiar with current power semiconductors, their mode of operation, and the most important characteristics and areas of application. • Be familiar with the passive devices and components of power electronics as well as their characteristics and parasitic effects. Be able to dimension the devices and components in a practical way. • Know the subject-specific fundamentals of electromagnetic fields and be able to apply these both for dimensioning purposes and for optimizing the electromagnetic compatibility of the circuits. • Be familiar with thermal calculations and be able to perform them specifically to improve the thermal management of power electronic assemblies.

	• Know the most important applications of electrical energy conversion in the field of renewable energies. Methodological skills: After completing this course, students will be able to apply interdisciplinary mathematical and physical principles specifically to analyze and optimize power electronic circuits. They will understand the design of practical circuits and be able to determine the essential functional parameters using both simulation and laboratory measurements. In addition, students will be able to independently research the state of the art of individual sub-areas in relevant sources and will understand how to communicate the essential results to their fellow students in the context of a short presentation.
Course contents	• Introduction: Electrical energy conversion by power electronics (fields of application, development goals, classification of circuits, power semiconductors available today, application examples) • Basics and definitions (characteristics of current and voltage signals, pointer diagrams, complex AC calculation, Fourier analysis, active, apparent and reactive power, power factor) • Multiphase systems (power terms, the 3-phase AC network, basic circuits for active and reactive power measurement, digital power measurement) • Power semiconductors (switching losses, diodes, thyristors, transistors: MOSFET, bipolar transistor and IGBT, turn-off thyristors: GTO and IGCT) • Topologies for different applications (transient switching, DC-DC converters, PFC circuits, flyback converters, resonant converters) • Introduction to thermal calculations (mechanisms of heat transfer, heat conduction, natural convection and forced convection, thermal radiation) • Passive devices and components (lines, cables and busbars, power and measuring resistors, coils, transformers, instrument transformers, capacitors) • Electromagnetic compatibility (conducted interference, radio interference suppression of power electronic circuits) • Applications in the field of renewable energies (photovoltaic systems, wind turbines, electric mobility, electric energy storage, active load flow control and reactive power compensation, high voltage direct current transmission)

Study / examination grades contributing to final grade	Written examination and seminar lecture
Other performance tests	None
Media:	Blackboard, projector, whiteboard, printed lecture notes with exercises, electronically provided accompanying material, seminar presentations by students on selected topics.
Literature:	P. Denzel, Grundlagen der Übertragung elektrischer Energie, Springer-Verlag, 1966, ISBN-10: 3642869009 K. Heuck, K.-D. Dettmann, D. Schulz, Elektrische Energie-versorgung: Erzeugung, Übertragung und Verteilung elektrischer Energie für Studium und Praxis, Verlag Springer Vieweg, 9th updated and corrected edition, 2013, ISBN-10: 383481699X R. Marenbach, D. Nelles, C. Tuttas, Elektrische Energietechnik: Grundlagen, Energieversorgung, Antriebe und Leistungs-elektronik, Verlag Springer Vieweg, 2013, ISBN-10: 3834817406 U. Probst, Leistungselektronik für Bachelors: Grundlagen und praktische Anwendungen, Carl Hanser Verlag GmbH & Co. KG, 2nd updated and expended edition, 2011, ISBN-10: 3446427341 A. J. Schwab, Elektroenergiesysteme: Erzeugung, Transport, Übertragung und Verteilung elektrischer Energie, Springer-Verlag, 1st edition, 2006, ISBN-10: 3540296646 J. Specovius, Grundkurs Leistungselektronik: Bauelemente, Schaltungen und Systeme, Verlag Springer Vieweg, 7th updated and revised edition, 2015, ISBN-10: 3658033088 F. Zach, Leistungselektronik: Ein Handbuch Band 1 / Band 2, Springer-Verlag, 4th completely revised and expanded edition, 2010, ISBN-10: 3211892133 A. Wintrich, U. Nicolai, W. Tursky, T. Reimann, Applikations-handbuch Leistungshalbleiter, SEMIKRON International GmbH, 2010, ISBN-10: 393884356X

Module name	**High Voltage Technology**
Abbrev.	Hsp
Format / SWH	Seminar-type lectures (3 SWH), practical course (1 SWH) / 4 SWH
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Semester	5
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Michael Rossner
Instructor(s)	Dr. Michael Rossner
Language	German
Use in other academic programs	-
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	Ph, GE1, Math 1 and 2
Qualification objectives / skills	Subject-related skills After the course students will: • Be able to calculate breakdown voltages in homogeneous and slightly inhomogeneous arrangements in air. • Know the different discharge forms in inhomogeneous arrangements. • Know the breakdown mechanisms in liquids and insulating materials. • Be able to undertake calculations for high voltage transformers according to the common equivalent circuit diagrams. • Be familiar with the circuits for the generation of high DC voltages. • Be able to calculate and/or estimate systematic measurement errors in HV measurement technology. • Be able to design, evaluate and perform surge voltage tests. • Be able to execute and evaluate PD measurements. • Be able to take measurements with the Shering bridge. • Be able to undertake calculations of multiple reflections in lossless lines.

	• Be able to calculate simple electric fields by themselves and understand the basics of numerical field calculation by means of small examples. Methodological competence After the course, students will be able to independently dimension high-voltage test and measurement setups according to common measurement and test methods and to independently perform corresponding measurements. They will have developed an understanding of the different discharge forms and be able to calculate breakdown voltages in simple geometries.
Course contents	Generation of high voltages; measurement of high voltages Measurement and test methods in high voltage technology Shering bridge (C - tan. Delta), partial discharge measurement techniques (AC + DC), surge voltage testing, and statistical evaluation methods, PDP measurement techniques Field calculation Breakdown mechanisms (gases, liquids, solids) Requirements for HV - DC technology Space-charged field, El. flow field, equivalent circuit diagrams, materials Propagation of transient overloads Practical course: - Generation and measurement of high AC voltages peak/peak; cap. overloads - Overload voltages 1.2/50 and statistics - DC voltage generation, doublers, discharge modes in inhomogeneous arrays - TE measurement and Shering bridge - FEM field simulation
Study / examination grades contributing to final grade	Written examination (90 minutes) and practical performance tests
Other performance tests	None
Media:	Blackboard, projector, whiteboard, Moodle platform Handouts and exercises provided in electronic format

Literature:	Andreas Küchler, "Hochspannungstechnik", Springer Verlag 2009, 3rd edition M. Beyer, W. Boeck, K. Möller, W. Zaengl, "Hochspannungstechnik, Theorie und praktische Grundlagen der Anwendung", Springer Berlin Heidelberg New York, 1986 G. Hilgarth, "Hochspannungstechnik" B.G. Teubner Stuttgart, 2nd edition 1992 Adolf Schwab, Hochspannungsmesstechnik, Springer Verlag 2nd revised edition 2011 Wolfgang Schluft, Taschenbuch der "Elektrischen Energietechnik" Hanser Verlag 2007 D. Kind, K. Feser "Hochspannungsversuchstechnik", Vieweg Verlag, 5th edition 1995 D. Kind, H. Kärner, "Hochspannungsisoliertechnik", Vieweg Verlag 1982

Module name	**Intelligent Energy Systems**
Abbrev.	IEs
Format / SWH	Seminar-type lectures (2 SWH), integrated exercise, practical course (2 SWH) / 4 SWH
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Semester	6
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Christian Weindl
Instructor(s)	Dr. Christian Weindl
Language	German
Use in other academic programs	Open to all 3 electrical engineering fields of study
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	Ph, GE1, Math 1 and 2
Qualification objectives / skills	Subject-related skills After the course students will: • Know the basic structure and operation of conventional electrical energy systems. • Understand and be able to describe the requirements and problems resulting from changes in the energy supply system. • Be able to describe and calculate central components and operating resources of intelligent energy systems. • Know the networked operation of regenerative power generators - smart generation. • Know the definition, structure, and basic operation of smart distribution systems. • Be able to calculate network and resource utilization for conventional and regenerative feed-in. • Be able to calculate and develop solutions for voltage maintenance in subgrids and feeder lines. • Know and be able to calculate active and reactive power transmission in electrical networks and the

	compensation needed for fluctuating regenerative feeders. • Know the operationally required network services and their provision by smart grids. • Be able to differentiate and evaluate different communication methods and technologies. • Be able to calculate simple electrical energy systems and analyze their operation. • Be able to classify legal framework conditions and apply them to the design, structural components and operation of the system. Methodological competence After the course, students will be able to understand intelligent energy systems and how the main components work, and will be able to analyze their operation. They will have developed an understanding of the technical, economic and legal framework and know solutions to ensure the communication tasks required in smart grids. They will also be able to perform basic calculations on the transmission behavior of electrical power grids and evaluate the results.
Course contents	Basic structure and interconnected operation of conventional electrical power supply networks Consequences of technical and economic change in energy supply and the energy transition Operating equipment of electrical power supply and components of smart grids Structure and operation of intelligent energy systems Network and resource utilization Voltage stability in medium-voltage and low-voltage grids Communication methods and technologies in smart grids Legal framework and market fundamentals Practical course: - Calculation/simulation of conventional electrical energy systems - Development of regenerative supply scenarios - Analysis and comparison of the operating principles and balancing processes within the grid structures - Development and simulation of procedures for balancing volatile active and reactive load flows

	- Investigation of alternative possibilities for the provision of grid services - Investigation of alternative possibilities for the provision of grid services
Study / examination grades contributing to final grade	Written examination (90 min.) and practical performance tests
Other performance tests	None
Media:	Blackboard, projector, whiteboard, Moodle platform Handouts and exercises provided in electronic format
Literature:	Bernd Michael Buchholz; Zbigniew Styczynski: "Smart Grids: Grundlagen und Technologien der elektrischen Netze der Zukunft", VDE Verlag, 2014 Elias Kyriakides; Siddharth Suryanarayanan; Vijay Vittal: "Electric Power Engineering Research and Education”, Chapter "Evolution of Smart Distribution Systems", Springer Verlag, 2014 James Momoh: "Smart Grid: Fundamentals of Design and Analysis”, Wiley-IEEE-Press, 2012 Janaka Ekanayake; Nick Jenkins; Kithsiri Liyanage; Jianzhong Wu; Akihiko Yokoyama: "Smart Grid: Technology and Applications”, John Wiley & Sons Publication, 1st edition, 2012 Gerhard Herold, "Elektrische Energieversorgung I", J. Schlembach Fachverlag, 2nd edition, 2005 Gerhard Herold, "Elektrische Energieversorgung II", J. Schlembach Fachverlag, 2nd edition, 2008

Module name	**Control Technology - Specialization Subject**
Abbrev.	Rt
Format / SWH	Seminar-type lectures with exercises / 4 SWH
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Semester	5
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Kolja Kühnlenz
Instructor(s)	Dr. Kolja Kühnlenz
Language	German
Use in other academic programs	AU, EL and EN
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	Basic knowledge of signal and system theory, solution methods for linear differential equations in the time and frequency domain
Qualification objectives / skills	• Students will: Be able to distinguish between the basic concepts of control and regulation and will know their essential characteristics. • Be able to analyze the behavior of mechanical, electrical, thermal, and other controlled systems and to describe them mathematically in the time and frequency domain. • Know the most important criteria for assessing control loop behavior and the most commonly used continuous controller types. • Know methods for assessing the stability of linear control loops and be able to apply them. • Understand basic design and optimization concepts for linear control loops and be able to apply them to simple examples.

Course contents	Basic structures and methods of control technology System description using differential equations Laplace and Fourier transforms Position curves and Bode diagrams Controlled systems Proportional controlled systems with delay Oscillatory proportional controlled systems Other typical controlled systems Simple linear control loops Basic structure and quality criteria Realization of controllers Control loops with P, PI and PID controllers Guidance and disturbance behavior Stability General stability considerations Hurwitz criterion Control loop design using Bode diagram and root locus curve
Study / examination grades contributing to final grade	Written examination 90 min.
Other performance tests	None
Media:	Blackboard/whiteboard and projector / overhead projector Electronically provided working documents and exercises
Literature:	Schulz G.: Regelungstechnik 1 Oldenbourg 2010 Zacher S., M. Reuter: Control Technology für Ingenieure Springer Vieweg 2014 Mann H., et al.: Einführung in die Control Technology Carl Hanser 2009

Module name	**Fluid Dynamics**
Abbrev.	Stm
Format / SWH	Seminar-type lectures (3 SWH), integrated exercises (1 SWH) / 4 SWH
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Semester	5
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Philipp Epple
Instructor(s)	Dr. Philipp Epple
Language	German
Use in other academic programs	
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	Foundations of physics and mathematics
Qualification objectives / skills	Calculation of forces and moments in hydrostatic systems Mathematical description of flows (kinematics) Solution of one-dimensional flow problems according to the streamline theory with the Bernoulli equation (energy) Calculation of forces in flows using the momentum equation Calculation of pipe flows
Course contents	Basic concepts hydrostatics fluid kinematics Incompressible flows, streamline theory Continuity equation, energy equation (Bernoulli) Momentum theorem Fundamentals of viscous flows Elements of laminar and turbulent flows Pipe flows

Final grades of study / examination:	Written examination, 90 minutes
Other performance tests	None
Media:	Chalk board, projector, supplemental written documents
Literature:	[1] Bohl, W., Elmendorf, W.: Technische Strömungslehre, 13th revised edition, Vogel Buchverlag, Würzburg, 2005 [2] Becker,E.: Technische Strömungslehre, Teubner Verlag, Stuttgart, 1969 [3] Becker,E., Piltz,E.: Übungen zur Technischen Strömungslehre, Teubner Verlag, Stuttgart, 1971 [4] Böswirth, L: Technische Strömungslehre, 8th edition, Vieweg+Teubner, Wiesbaden 2010 [5] Durst, Franz: Grundlagen der Strömungsmechanik - Eine Einführung in die Theorie der Strömungen in Fluiden, Springer Verlag, Berlin, 2006 [6] Fox, Robert W., McDonald, Alan T.: Introduction to Fluid Mechanics, Fifth Edition, John Wiley & Sons, Inc., New York, 1998 [7] Kuhlmann, Hendrik: Strömungsmechanik, Pearson Studium Verlag, 2007 [8] Kümmel, W.: Technische Strömungsmechanik - Theorie und Praxis, Teubner Verlag, 2007 [9] Oertel Jr., Herbert und Böhle, Martin: Strömungsmechanik - Grundlagen, Grundgleichungen, Lösungsmethoden, Softwarebeispiele, 2nd revised and expanded edition, Vieweg & Sohn [10] Siekmann, Helmut E.: Strömungslehre für den Maschinenbau, Technik und Beispiele, Springer Verlag Berlin, 2001 [11] Sigloch, Herbert: Technische Fluidmechanik, VDI-Verlag, 1996 [12] Zierep, J, Bühler, K.: Grundzüge der Strömungslehre, 8th edition, Vieweg+Teubner, 2010

Module name	**Thermodynamics**
Abbrev.	Tdyn
Format / SWH	Seminar-type lectures, integrated exercises / 4 SWH
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Semester	5
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Bernd Hüttl
Instructor(s)	Dr. Bernd Hüttl
Language	German
Use in other academic programs	-
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	Ph, Math 1 and Math2
Qualification objectives / skills	Subject-related skills After the course, students will be able to: • Apply the technical knowledge of engineering thermodynamics and describe thermodynamic systems using relevant state variables. • Represent thermodynamic processes based on ideal gases and real vapors using appropriate diagrams and model the changes of state. • Describe circular processes of renewable Power Engineering qualitatively and quantitatively, • Understand, quantitatively describe and technically evaluate processes of energy conversion, energy transfer and flows.
Course contents	• **Fundamentals of technical thermodynamics** Students will learn about the basic thermodynamic state variables and the main theorems of thermodynamics; the calculation of state and mass changes in thermodynamic systems; modeling of energy balances; and work processes in closed and open systems. • **Thermodynamic circular processes**

	Students will be familiar with the description and quantification of circular processes in renewable power engineering using real working media (e.g. gas and steam turbines, heat pumps, combined heat and power plants, Stirling engine). • **Processes of energy generation and energy transmission** Students will learn about and be able to calculate energy generation and energy conversion processes of renewable power engineering (e.g. fuel cells, photothermal systems, combustion processes and thermal storage).
Study / examination grades contributing to final grade	Written examination 90 min.
Other performance tests	None
Media:	Blackboard, projector, Moodle platform Handouts and exercises provided in electronic format
Literature:	E. Doering, H. Schedwill, M. Dehli: Grundlagen der Technischen Thermodynamik, Teubner Verlag G. Cerbe, G. Wilhelms: Technische Thermodynamik, Hanser Verlag D. Labuhn, O. Romberg: Keine Panik vor Thermodynamik, Vieweg + Teubner Verlag

Module name	**Wind Energy**
Abbrev.	We
Format / SWH	Seminar-type lectures (2 SWH), exercise (2 SWH) / 4 SWH
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Semester	6
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Michael Rossner
Instructor(s)	Dr. Philipp Epple, Dr. Omid Forati Kashani
Language	German
Use in other academic programs	-
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	Previous knowledge of machines and power converters would be beneficial.
Qualification objectives / skills	Students will master aerodynamic calculation and the design of wind turbines. They will know the generation paths of electrical energy by synchronous generators, asynchronous generators, or doubly fed three-phase machines and the application of the relevant power converters for the connection of the generators to the grid.
Course contents	• Topics on fluid mechanics and mechanics: - Fundamentals of fluid mechanics: continuity equation, energy equation, and momentum equation. - Resistance rotor - Buoyancy rotor - Classification of wind turbines - Wind: wind power, atmospheric boundary layer, near-ground boundary layer, height profile of wind, frequency distribution and distribution functions, wind measurement and evaluation - Design of wind turbines according to Betz: linear momentum theory

	- Airfoil theory, wind triangles, air forces at the rotating blade - Betz optimal design - Losses: airfoil losses, tip losses, swirl losses - Design of wind turbines according to Schmitz considering swirl losses - Characteristic diagram calculation and partial load behavior - Dimensionless representation of characteristic curves - High-speed and low-speed rotor - Turbine maps - Behavior of high-speed turbines with pitch adjustment - Starting and idling range - Limits of the blade element method and three-dimensional calculation methods - Dynamic flow separation - Singularity method - Numerical flow simulation - Model laws and similarity rules • Topics on generators and power converter technology: - Fundamentals of the generation of the rotating field and the three-phase voltage system - Synchronous machine, types, construction, mode of operation, and characteristic curves - Asynchronous machine, types, construction, operation, and characteristics - Doubly-fed three-phase machine, construction, principle of operation, and characteristics - Converter topologies for wind turbines, their operation, and characteristic curves - Control of asynchronous and synchronous generator and double-fed three-phase machine together with converter - Dynamic behavior of the generator-converter unit on the grid - Harmonics due to power converter supply to the network
Study / examination grades contributing to final grade	Written examination, 90 minutes
Other performance tests	None
Media:	Blackboard, overhead/ projector/ visualizer/ whiteboard Supplementary written material or electronically provided working material and exercises

Literature:	[1] Dixon, S. and Hall, C.: Fluid Mechanics and Thermodynamics of Turbomachinery, 7th edition, Butterworth-Heinemann, Oxford, 2014 [2] Gasch, R. und Twele, J.: Windkraftanlagen, Grundlagen, Entwurf, Planung und Betrieb, 7th updated edition, Vieweg Teubner Verlag, Wiesbaden 2011. [3] Hau, E: Windkraftanlagen: Grundlagen, Technik, Einsatz, Wirtschaftlichkeit, 4th edition, VDI Buch, Springer Verlag, Heidelberg, 2008 [4] Heier, S.: Windkraftanlagen, 5th edition, Vieweg Teubner, Wiesbaden, 2009 [5] Schaffarczyk, A.: Introduction to Wind Turbine Aerodynamics, Springer Verlag, Heidelberg 2014 [6] Watter, H.: Nachhaltige Energiesysteme, Vieweg Teubner, Wiesbaden 2009 [7] Fischer, R.: Elektrische Maschinen, Karl Hanser Verlag Munich, 2011 [8] Skudelny, H.C.: Stromrichtertechnik, Verlag der Augustinus Buchhandlung, 1997 [9] CEwind eG / Alois Schaffarczyk (publ.), Einführung in die Windenergietechnik, Hanser Verlag, 2012 [10] Stiebler, M.: Wind energy systems for electric power generation, Springer Verlag, 2008 Späth, H.: Steuerverfahren für Drehstrommaschinen: Theoretische Grundlagen, Springer Verlag, 1983

3.2 Compulsory elective module

Module name	**Renewable Energies**
Abbrev.	EE
Format / SWH	Seminar-type lectures, exercises and practical course integrated into one specialization area
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Semester	7
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Michael Rossner
Instructor(s)	Dr. Michael Rossner / Dr. Christian Weindl / Dr. Alexander Stadler / Dr. Bernd Hüttl
Language	German
Use in other academic programs	-
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	Electrical measurement technology, fundamentals of electrical engineering and electronic components
Qualification objectives / skills	Subject-related skills After the course, students will be able to: • Measure the electrical behavior of photovoltaic generators (modules or strings) under field conditions and evaluate them in comparison to laboratory standard analyses. • Measure the meteorological variables relevant to photovoltaic yield and use them for accurate simulations. • Perform yield calculations for PV power plants by using the simulation program PVSyst. • Assess the requirements of regenerative energy feed-in to transmission grids.

	• Simulate the behavior of interconnected electrical systems and transmission grids, and analyze weak points and overload situations. • Use suitable resources to ensure and increase the stability and security of supply in the transmission grid. Methodological competence After the course, students will be able to: • Apply essential measurement methods of outdoor photovoltaics in a safe and practical manner. • Create yield simulations. • Carry out and evaluate weak point analyses in electrical interconnected systems by means of simulation calculations. • Investigate and evaluate the use and options of modern semiconductor-based three-phase power supplies.
Course contents	**Determination of electrical parameters of PV generators under field conditions** Students will be able to incorporate spectral, direct and diffuse characteristics of solar radiation, albedo, temperature and module geometry to determine STC short-circuit current and all other PV generator electrical parameters. **Determination of the field behavior of PV generators using the "Self-Reference-Algorithm" (SRA)** Students will be introduced to the SRA and be able to apply the method to a measurement campaign for generating temperature-dependent, low-light characteristics for relevant characteristic parameters (Isc, Voc, Pmpp, FF,) of the PV generator. **Yield analyses** Students will be familiar with the yield simulation software PVSyst and the yield-optimized design of PV systems ("roof-top, "building-integrated PV", field systems). **Determining the requirements for regenerative electrical transmission grids** Students will understand and be able to interpret the additional requirements resulting from a significantly renewable and volatile use (e.g. PV and wind energy) of the grids. **Weak point analysis by simulation of a model network of an electrical transmission system**

	Students will be introduced to basic procedures for the analysis of weak points in electrical networks and be able to apply them. **Project planning and examination of modern semiconductor-based three-phase power supplies** Students will be familiar with FACTS (Flexible AC Transmissions Systems) in a model network and their planning (design and positioning).
Study / examination grades contributing to final grade	Examination (90 min). and practical training research paper in one of the offered specializations
Other performance tests	Practical training research paper as prerequisite for admission to examination
Media:	Blackboard, projector, Moodle platform Electronically provided documents and project tasks
Literature:	V. Quaschning: Regenerative Energiesysteme, Hanser Verlag H. Häberlin: Photovoltaik, VDE Verlag, Bernd Michael Buchholz; Zbigniew Styczynski: "Smart Grids: Grundlagen und Technologien der elektrischen Netze der Zukunft", VDE Verlag, 2014 Janaka Ekanayake; Nick Jenkins; Kithsiri Liyanage; Jianzhong Wu; Akihiko Yokoyama: "Smart Grid: Technology and Applications", John Wiley & Sons Publication, 1st edition , 2012

Module name	**Foundations of Electrical Engineering 3**
Abbrev.	GE3
Format / SWH	Seminar-type lectures (2.5 SWH), exercise (1.5 SWH) / 4 SWH
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Semester	5
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Matthias Mörz, Dr. Alexander Stadler
Instructor(s)	Dr. Matthias Mörz, Dr. Alexander Stadler
Language	German
Use in other academic programs	AU, EL and EE
Admission requirements	Eligibility to advance pursuant to §6 Para. 1 SPO
Prerequisites	Fundamentals of electrical engineering, signals and systems, mathematics
Qualification objectives / skills	After the course students will be able to: • Describe electrical networks as four-poles with different four-pole representations. • Set up and convert four-pole parameters. • Calculate operating parameters of four-poles. • Interconnect different four-poles and calculate the total four-pole representation. • Interconnect four-poles with three-poles. • Understand and determine simplified arrangements for practical field problems. • Solve one-dimensional field problems of electrostatics, flow field, magnetostatics, and induction problems using field approximation methods. • Set up and explain Maxwell's equations. • Understand and calculate skin effect problems.
Course contents	• Four-poles • Complex description of voltage and current • Operating characteristics of four-poles • Four-pole representations • Interconnection of four-poles • Calculation of operating parameters

	• Conversion of four-pole parameters • Interconnection of four-poles with three poles • Electrostatics • Magnetostatics • Flow field • Law of induction • Maxwell's equations • Skin effect
Study / examination grades contributing to final grade	Written examination (120 minutes)
Other performance tests	None
Media:	Projector and blackboard/whiteboard, simulation programs, electronic scripts and working documents
Literature:	Wilfried Weißgerber: Elektrotechnik für Ingenieure 3, Vieweg + Teubner Eugen Philippow: Grundlagen der Elektrotechnik, Verlag Technik Karl Küpfmüller, Wolfgang Mathis, Albrecht Reibinger: Theoretische Elektrotechnik, Springer Paul A. Tipler, Gene Mosca, Michael Basler, Renate Dohmen: Physik, Spektrum H. Buchholz, Elektrische und magnetische Potentialfelder, Springer-Verlag, 1957, ISBN-10: 3642480659 G. Lehner, Elektromagnetische Feldtheorie: für Ingenieure und Physiker, Springer-Verlag, 6th edition, 2008, ISBN-10: 3540776818 G. Mrozynski, Elektromagnetische Feldtheorie - Eine Aufgabensammlung, Vieweg+Teubner Verlag, 1st edition, 2003, ISBN-10: 3519004399

Module name	**Network and Equipment Diagnostics**
Abbrev.	NBd
Format / SWH	Seminar-type lectures (3 SWH), integrated exercise, practical course (1 SWH) / 4 SWH
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Semester	7
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Christian Weindl
Instructor(s)	Dr. Christian Weindl
Language	German
Use in other academic programs	Open to all 3 electrical engineering fields of study
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	Physics, GE1, Math 1 and 2
Qualification objectives / skills	Subject-related skills After the course students will: • Know the structure of important operating equipment and insulation systems. • Understand the operation of electrical networks and the influences of liberalization and regenerative use. • Understand the physical fundamentals of aging processes at different loads. • Understand dielectric diagnostic methods, diagnostic quantities, and dielectric materials. • Understand partial discharge measurements, methods for locating and online monitoring, & how to interpret them. • Be familiar with DC-based diagnostic methods & spatially resolved dielectric methods. • Know the physical characteristics and equivalent circuit diagrams of electrical insulating materials. • Be able to classify models for condition description & residual life estimation. • Be familiar with reliability, failure probability and failure distributions.

	• Understand and be able to apply different aging models: Arrhenius model, inverse power-law, multifactor aging models Methodological competence After the course, students will be able to understand and classify the variables influencing the network and equipment loads on the components of electrical power systems. They will have developed an understanding of the effects of loads on the operation, maintenance and asset management of plants, and will be familiar with procedures for implementing economic measures and strategies in these areas using diagnostic methods, i.e. based on the condition of the operating equipment.
Course contents	Structure of important operating equipment of electrical power supply networks and the insulation systems used Operating mode of electrical networks - influences of liberalization and decentralized, regenerative use Physical basics of aging processes: thermal, (di)electrical, mechanical aging processes. Dielectric diagnostic methods: primitivity, polarization, polarization modes, loss angle, loss factor, and capacitance of dielectric materials Partial discharge measurements: mode of operation and measurement principle, principle classification, limits and interpretation, methods for locating and online monitoring DC-based diagnostic methods & procedures for spatially resolved measurement of dielectric properties Differentiation of losses and dependencies of dielectric characteristics (f, T, U, operating age, etc.) Physical characteristics & equivalent circuit diagrams of electrical insulating materials Models for condition description & residual life evaluation, description of aging condition & residual life Methods for determining aging behavior: condition evaluation criteria, statistics, data reduction. Reliability, failure probability , failure distributions: bathtub curves, normal and Weibull distributions. Properties of aging models: Arrhenius model, inverse power-law, multifactor aging models Practical course:

	- Dielectric measurements and comparison of differently pre-aged medium voltage cables at 50 Hz. - Analysis of DC-based diagnostic measurements for qualitatively different test specimens - Development of condition criteria and limit values based on the measurement results Calculations of equipment loads, aging factors, and failure probabilities
Study / examination grades contributing to final grade	Written examination 90 min. and practical performance tests
Other performance tests	None
Media	Blackboard, projector, whiteboard, Moodle platform Handouts and exercises provided in electronic format
Literature	E. Ivers-Tiffee and W. Münch, Werkstoffe der Elektrotechnik. Wiesbaden: Teubner-Verlag, 2007 Wayne Nelson, Accelerated Testing - Statistical Models, Test Plants and Data Analysis. New-Jersey: John Wiles & Sons Inc., 1990 Klaus Graebig, Formelsammlung zu den statistischen Methoden des Qualitätsmanagements, 3rd ed., DGQ - Deutsche Gesellschaft für Qualität e.V., Ed. Berlin: Beuth-Verlag, 2006 Strömer, Mathematische Theorie der Zuverlässigkeit - Einführung und Anwendung. Munich, Vienna: Oldenburg Verlag, 1983 W. Mosch and W. Hauschild, Statistical Techniques for HV Engineering. LondonGreat Britain, United Kingdom: Peter Peregrinus, 1992 Power & Energy Society IEEE, "IEEE Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems", IEEE - Institute of Electrical and Electronics Engineers, Standard 400-2001 2001 Andreas Küchler, Hochspannungstechnik. Berlin: Springer-Verlag, 2009 G. Herold, Elektrische Energieversorgung I: Drehstromsysteme - Leistungen - Wirtschaftlichkeit., 3rd ed. Willburgstetten: J. Schlembach Fachverlag, 2011 G. Herold, Elektrische Energieversorgung II: Parameter Elektrischer Stromkreise - Freileitungen und Kabel - Transformatoren, 2nd ed. Willburgstetten: J. Schlembach Fachverlag, 2008

Module name	**Photovoltaics**
Abbrev.	PV
Format / SWH	Seminar-type lectures (3 SWH), integrated exercise, practical course (1 SWH) / 4 SWH
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Semester	6
Schedule	Annual
Duration of module	Single semester
Module coordinator	Dr. Bernd Hüttl
Instructor(s)	Dr. Bernd Hüttl
Language	German
Use in other academic programs	
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	Foundations of electrical engineering, electronic components and physics
Qualification objectives / skills	Subject-related skills After the course, students will be able to: • Use the knowledge and skills acquired in the basic studies to qualitatively and quantitatively understand and describe the mode of operation of photovoltaic systems. • Electrotechnically describe and design photovoltaic systems (including self-consumption systems with energy management) in terms of their main components. • Understand energy meteorological aspects of solar radiation and prepare and analyze yield forecasts for photovoltaic systems. • Perform laboratory measurements on photovoltaic components also under standard conditions and determine the essential technical parameters. Methodological competence After the course, students will be able to apply essential measurement methods of photovoltaics in a safe and practical manner.

	Social competence Practical work in project groups develops students' ability to solve tasks in a team.
Course contents	• **Energy meteorological aspects** Students will learn about the spectral, direct and diffuse properties of solar radiation as well as solar energy supply on inclined photovoltaic generators. • **Semiconductor technological aspects of solar cells and modules** Students will gain more in-depth knowledge on the pn semiconductor model and its application to solar cells; the handling of specific parameters of solar cells and the calculation of solar cell efficiency; the interconnection of solar cells to modules; cell technologies (manufacturing, properties, applications). • **Photovoltaic system technology** Students will learn about the main components of grid-connected and stand-alone systems (generators, string technologies, inverters, grid interconnection systems, storage and energy management systems) and how these components are designed. • **Yield calculations** Students will learn how to prepare yield forecasts based on irradiation conditions and system technology and how to evaluate economic efficiency.
Study / examination grades contributing to final grade	Written examination (60 minutes) and practical performance tests
Other performance tests	Practical course as examination admission requirement
Media:	Blackboard, projector, Moodle platform Handouts and exercises provided in electronic format
Literature:	V. Quaschning: Regenerative Energiesysteme, Hanser Verlag H. Häberlin: Photovoltaik, VDE Verlag I. Wesselak, T. Schabbach: Regenerative Energietechnik, Springer Verlag K. Mertens: Photovoltaik, Hanser Verlag

Module name	**Project Renewable Energies 1**
Abbrev.	En1Pr
Format / SWH	Project paper / 4 SWH
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Semester	5 (or 7)
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Michael Rossner
Instructor(s)	Professors from the academic program Power Engineering and Renewable Energies
Language	German
Use in other academic programs	
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	Knowledge in the compulsory modules of renewable energies. Fundamentals of high voltage technology, electrical energy conversion, and thermodynamics.
Qualification objectives / skills	**Subject-related skills** After the course students will: • Have in-depth experience in the fields of photovoltaics or power electronics or high voltage engineering. • Be able to apply specific simulation tools. • Know specific measurement methods. • Be able to create independent problem-related experimental setups. • Be able to evaluate and interpret complex measurement tasks. • Be able to perform independent, problem-related research. **Interdisciplinary skills** Methodological competence • Planning and managing projects in the field of renewable energies Social competence • Working on projects in a team

	Self-competence • Managing projects independently in terms of time and task allocation
Course contents	Students will work on changing tasks from the field of renewable energies. The projects are based on the following main topics: • Electric and magnetic fields • Coupling of electrical and thermal phenomena • Special requirements of measurement technology • Evaluation of large data sets Different simulation tools are used.
Final grades / examinations:	Project paper
Other performance tests	None
Media	
Literature	Project-dependent

Module name	**Project Renewable Energies 2**
Abbrev.	En2 Pr
Format / SWH	Project paper / 4 SWH
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Semester	6
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Michael Rossner
Instructor(s)	Professors from the academic program Power Engineering and Renewable Energies
Language	German
Use in other academic programs	
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	Knowledge in the compulsory modules of renewable energies. Fundamentals of high voltage technology, electrical energy conversion, and thermodynamics.
Qualification objectives / skills	**Subject-related skills** After the course students will: • Have in-depth experience in the fields of photovoltaics or power electronics or high voltage engineering. • Be able to apply specific simulation tools. • Know specific measurement methods. • Be able to create independent problem-related experimental setups. • Be able to evaluate and interpret complex measurement tasks. • Be able to perform independent, problem-related research. **Interdisciplinary skills** Methodological competence • Planning and managing projects in the field of renewable energies Social competence • Working on projects in a team

	Self-competence • Managing projects independently in terms of time and task allocation
Course contents	Students will work on changing tasks from the field of renewable energies. The projects are based on the following main topics: • Electric and magnetic fields • Coupling of electrical and thermal phenomena • Special requirements of measurement technology • Evaluation of large data sets Different simulation tools are used.
Final grades / examinations:	Project paper
Other performance tests	None
Media	
Literature	Project-dependent

Module name	**Control of Electric Drives and Power Converters**
Abbrev.	ReAS
Format / SWH	Seminar-type lectures (2 SWH), exercise (1 SWH), practical course (1 SWH) / 4 SWH
Credit points	5 ECTS
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Semester	6
Schedule	Semi-annually
Duration of module	Single semester
Module coordinator	Dr. Omid Forati Kashani
Instructor(s)	Dr. Omid Forati Kashani
Language	German
Use in other academic programs	AU, EE
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	Previous knowledge on the structure, mode of operation, and various characteristics of direct current, asynchronous and synchronous machines, and knowledge on power converters from the subjects "Electrical Drives and Networks" and "Electrical Drives and Power Converters".
Qualification objectives / skills	Students will know the basic control engineering tasks in drive and converter technology and be able to analyze and process these tasks. They will be able to mathematically describe and model the mechanical as well as the electrical subsystem of a drive, consisting of the converter, the drive machine and the load machine, based on their mode of operation. They will know the dynamic model of the DC machine, the synchronous and the asynchronous machine, and the converter, and be able to integrate these into control loops, analyze the control loops and design controllers for the drives with these machines according to the quality parameters. Based on the control of the three-phase drives, students will know the control of the grid-side converter (rectifier) and can design controllers for this converter. They will be able to verify their knowledge by simulations or practical experiments and to deepen their knowledge on the subject.

Teaching content	• Basic tasks in drive and converter technology • Mechanical subsystem (modeling of a rigid compound and a two-mass oscillator, torsional moment of a cylindrical shaft, basic speed control of a rigid compound consisting of the electric drive machine and the load machine, control engineering quality criteria, controller design according to symmetrical and absolute optimum) • Electrical subsystem with the direct current machine (review of the mode of operation of the direct current machine, model formation of the direct current machine) • Control of a drive with a direct current machine (speed and torque or current control of the direct current machine, quality criteria and controller design, mode of operation and control of the brushless direct current machine) • Electrical subsystem with the three-phase machines (operation and modeling of the synchronous and asynchronous machines, space vector, space vector representation of the currents and the voltages of three-phase winding systems, transformation and back transformation between the polar and the Cartesian coordinate system, transformation and back transformation between stationary and rotating coordinate system, active and reactive power with space vector components) • Control of a drive with the three-phase machines (current control in the rotating coordinate system, description of the controlled system, decoupling of the moment-forming and field-forming current control loops) • Control of the synchronous machine (synchronous motor with frequency control, dynamic description of the synchronous machine in the rotor-oriented coordinate system, rotor flux-oriented control, stator flux-oriented control, converter motor) • Control of the asynchronous machine (asynchronous machine with voltage-frequency control, asynchronous motor with stator current rotor frequency control, model of the asynchronous machine in the rotor-flux-oriented coordinate system, rotor flux- or field-oriented control of the asynchronous machine, indirect field orientation, rotor flux determination by using the

	voltage or current model, and combination of voltage and current models) • Control of the grid-side converter (requirements for the grid-side converter, review of the grid-guided and self-guided converter, control of a self-guided converter, control of a circuit-current-free or circuit-current-affected reverse converter, current control loop of the grid-side self-guided converter in the rotating coordinate system, grid synchronization by PLL, space vector modulation) • Actual value acquisition in the control of electric drives and power converters (current acquisition, voltage acquisition, position or speed acquisition)
Study / examination grades contributing to final grade	Written examination (90 minutes) and practical performance tests
Other performance tests	None
Media:	Blackboard, overhead/ projector/ visualizer/ whiteboard Electronically provided working documents and exercises, practical exercises on the test bench in the laboratory
Literature:	- Werner Leonard, Regelung elektrischer Antriebe, Springer Verlag, 2000 - Dirk Schröder, Elektrische Antriebe - Grundlagen, Springer Verlag, 2009 - Dirk Schröder, Elektrische Antriebe - Regelung von Antrieben, Springer Verlag, 1994 - Gerhard Pfaff, Regelung elektrischer Antriebe I – Eigenschaf- ten, Gleichungen und Strukturbilder der Motoren, Oldenburg Verlag, 1991 - Gerhard Pfaff, Regelung elektrische Antriebe II – Geregelte Gleichstromantriebe, Oldenburg Verlag, 1988 - Helmut Späth, Steuerverfahren für Drehstrommaschinen: Theoretische Grundlagen, Springer Verlag, 1983
Course contents	Practical experiments are carried out on the following topics: • Modeling and parameter determination of a DC motor. • Control and disturbance behavior of the current control loop of a DC motor.

	• Control loop design for an oscillating section with compensation and a dead time section. • Speed control of a motor according to the symmetrical optimum. • Position control as a control loop cascade - speed amplification and following error. • Control of an unstable path - inverse pendulum.
Study / examination grades contributing to final grade	Practical training research paper with experimental work, colloquium
Other performance tests	None
Media:	Electronically provided experimental documents, experimental setups in the laboratory, simulation programs on the computer
Literature:	Schulz G.: Regelungstechnik 1 Oldenbourg 2010 Probst U.: Servoantriebe in der Automatisierungstechnik Vieweg und Teubner 2011

Module name	**Practical Course in Control Technology**
Abbrev.	RtP
Format / SWH	Practical course / 2 SWH
Credit points	2.5 ECTS
Work requirement	In-class time: 30 hrs, self-study: 45 hrs.
Semester	7
Schedule	Annually
Duration of module	Single semester
Module coordinator	Dr. Kühnlenz
Instructor(s)	Dr. Kühnlenz
Language	German
Use in other academic programs	AU, EL and EE and EN
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	Solid foundation in control technology methods and concepts
Qualification objectives / skills	• Students will be able to apply the basic methods of control technology to practical control loops. • They will be able to determine distance parameters, which determine the transmission behavior, using measurement technology. • They will be able to carry out a theoretical and simulation-based controller design. • They will be able to put a control loop into operation for different controlled systems and to optimize the controller parameters with regard to control or disturbance behavior. • They will be able to assess the stability of control loops and will know which measures can be taken to improve it.
Course contents	Practical experiments are carried out on the following topics: • Modeling and parameter determination of a DC motor. • Control and disturbance behavior of the current control loop of a DC motor. • Control loop design for an oscillating section with compensation and a dead time section.

	• Speed control of a motor according to the symmetrical optimum. • Position control as a control loop cascade - speed amplification and following error. • Control of an unstable path - inverse pendulum.
Study / examination grades contributing to final grade	Practical training research paper with experimental work, colloquium
Other performance tests	None
Media:	Electronically provided experimental documents, experimental setups in the laboratory, simulation programs on the computer
Literature:	Schulz G.: Regelungstechnik 1 Oldenbourg 2010 Probst U.: Servoantriebe in der Automatisierungstechnik Vieweg und Teubner 2011

Module name	**Field Simulation Methods and Applications**
Abbrev.	VAFs
Format / SWH	Seminar-type lectures with integrated exercises (1 SWH), computer practical course (3 SWH) / 4 SWH
Credit points	5/6 ECTS (depending on academic program)
Work requirement	In-class time: 60 hrs, self-study: 90 hrs.
Semester	5-7
Schedule	Semi-annually
Duration of module	Single semester
Module coordinator	Dr.-Ing. Alexander Stadler
Instructor(s)	Dr.-Ing. Alexander Stadler
Language	German
Use in other academic programs	AU, EE, EL, EN
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	Mathematics, basics of electrical engineering, basic PC and programming skills
Qualification objectives / skills	• Knowledge: Students will learn about the methods and applications of field simulations to solve practical problems and deepen their basic knowledge on field theory, the set-up of Matlab scripts and functions, the pictorial representation of two and three dimensional field quantities, and numerical integration over lines, areas and volumes. • Skills: They will be able to simplifying practical field problems, create simple Matlab scripts and functions to evaluate given field approaches, numerically evaluate the approaches on edges and in domains, troubleshoot the program in a structured way by using the Matlab help function, and compare the solutions to known approximation formulas. • Competencies: Students will be able to analyze foreign program code and modify it to solve new problems. They will deepen their basic knowledge on field theory through pictorial representation and numerical evaluation of field quantities and learn how to deal with new, unfamiliar mathematical functions.
Course contents	• Introduction to Matlab

	• Practical examples and repetition exercises • Programming exercises on electrostatics and magnetostatics, the flow field as well as the law of induction and Maxwell's equations
Study / examination grades contributing to final grade	Written examination (90 min) and seminar lecture (master courses)
Other performance tests	None
Media:	Blackboard lecture, presentation with laptop/beamer, printed exercise script and programming exercises in computer room
Literature:	H. Buchholz, Elektrische und magnetische Potentialfelder, Springer-Verlag, 1957, ISBN-10: 3642480659 G. Lehner, Elektromagnetische Feldtheorie: für Ingenieure und Physiker, Springer-Verlag, 6th edition, 2008, ISBN-10: 3540776818 G. Mrozynski, Elektromagnetische Feldtheorie – Eine Aufgabensammlung, Vieweg+Teubner Verlag, 1st edition, 2003, ISBN-10: 3519004399 M. Abramowitz, I. Stegun, Handbook of Mathematical Functions, Dover Publications Inc., 9th edition, 1970, ISBN-10: 0486612724 J. D. Jackson, Classical Electrodynamics, John Wiley & Sons, 3rd edition, 1998, ISBN-10: 047130932X W. B. Smythe, Static and Dynamic Electricity, Taylor & Francis, 3rd edition, 1989, ISBN-10: 0891169172

Module name	**Hydroelectric Power**
Abbrev.	Wk
Format / SWH	Seminar-type lectures, integrated exercises / 4 SWH
Credit points	5 ECTS
Work requirement	In-class 60 hrs, self-study 60 hrs.
Abbrev.	Wk
Semester	6
Schedule	Annual
Duration of module	Single semester
Module coordinator	Dr. Michael Rossner
Instructor(s)	Dipl.-Ing. Hans-Peter Würl
Language	German
Use in other academic programs	Automation Technology and Robotics, Electrical Engineering and Information Technology
Admission requirements	Eligibility to advance pursuant to §6 Para. 2 SPO
Prerequisites	Basic studies (1 to 4) in the courses of study: Automation Technology and Robotics, Electrical Engineering and Information Technology, Renewable Energies
Qualification objectives / skills	• Knowledge of potential as well as the possible use of water energy • Knowledge of the most important turbine and power plant types and their characteristics • Knowledge of the most important plant concepts • Basics in potential estimation of hydropower
Course contents	• Basics and development of hydropower in Germany-Europe-World, including historical development • Potential and utilization of hydropower • Hydrological and hydraulic basics • Components of hydropower plants and their design (types of hydropower, operation, turbine types) • Environmental impact (fishways) • Ecological and economic aspects of hydropower utilization • Site selection and design of hydropower • Small hydropower (SHPP) • Hydropower without impoundment

	• Storage power plants (basics of pumped storage) • EEG and hydropower plants • Wave energy and ocean current power plants
Study / examination grades contributing to final grade	Lecture as preparation for excursion and excursion report, 60 min. examination
Other performance tests	None
Media:	Overhead projector, computer / projector, PDF slides Part 1 and Part 2 of slides in printed form, others as PDF file
Literature:	• Giesecke, J., Heimerl, S., Mosonyi, E., 2014: **Wasserkraftanlagen,** Springer-Verlag • Patt, H., Gonsowski, P., 2011: **Wasserbau,** Springer-Verlag • EM. Prof. Dr.-Ing. Raabe, J., 1989: **Hydraulische Maschinen und Anlagen,** VDI Verlag • Prof. Dr. Mosonyi, E., 1966: **Wasserkraftwerke** Volume I and II, VDI Verlag • W. Müller, 1983: **Die Wasserräder,** M. Schäfer Verlag • Schneider, 2010: **Bautabellen für Ingenieure,** Werner Verlag • **DWA-Regelwerk** (fact sheets, worksheets) • **DIN 19752,** Hydropower plants • **VDI Richtlinie 4620**, Hydropower plants The above mentioned textbooks/guidelines are available/viewable in the university library and/or some are available as an e-book!

4. Thesis Papers

Module name	**Bachelor Thesis**
Format / SWH	BT
Credit points	12 ECTS
Work requirement	Self-study 360 hrs.
Abbrev.	
Semester	7
Schedule	Semi-annually
Duration of module	Single semester
Module coordinator	Dr. Michael Rossner
Instructor(s)	Professors of the E/IF department
Language	German
Use in other academic programs	AU, EL and EE
Admission requirements	Eligibility to advance pursuant to §6 Para. 3 SPO
Prerequisites	None
Qualification objectives / skills	Technical and methodological objectives: Students will be able to independently work on and solve a complex task from their academic program on a scientific basis.
Course contents	Depending on the topic of the Bachelor thesis
Study / examination grades contributing to final grade	Bachelor Thesis
Other performance tests	None
Media:	---
Literature:	H. Balzert, M. Schröder, C. Schäfer: Wissenschaftliches Arbeiten. W3L-Verlag, Dortmund, 2011, Subject-specific literature

Module name	**Bachelor Seminar**
Abbrev.	BcSem
Format / SWH	Seminar / 2 SWH
Credit points	3 ECTS
Work requirement	In-class time: 30 hrs, self-study: 60 hrs.
Semester	7
Schedule	Semi-annually
Duration of module	Single semester
Module coordinator	Dr.-Ing. Matthäus Brela
Instructor(s)	Professors of the FEIF department
Language	German
Use in other academic programs	AU, EE, EN and EL
Admission requirements	Eligibility to advance pursuant to §6 Para. 3 SPO
Prerequisites	None
Qualification objectives / skills	• Students will be able to report on an engineering problem in front of an expert audience. • They will be able to present a task they have worked on themselves in a structured manner and embedded in the scientific context. • They will critically study their own results and be able to represent them in a qualified manner in the discussion. • They will deal critically with other students' presentations and be able to clarify factual questions in a professional manner.
Course contents	Depending on the topics of the current bachelor theses
Study / examination grades contributing to final grade	Final 20 minute presentation on the contents of the student's own Bachelor's thesis, followed by a discussion
Other performance tests	Participation in 3 other seminar lecture series with 3-5 seminar lectures each
Media	Projector / if needed: blackboard or Whiteboard

Literature	H. Balzert, M. Schröder, C. Schäfer: Wissenschaftliches Arbeiten. W3L-Verlag, Dortmund, 2011