Electrical power conversion and delivery

Electrical power conversion and delivery	
Offered by	Department of Electrical Engineering
Language	English
Primarily interesting for	All students, but most relevant for students with background in EE and AT, and SI, Inf, Wsk, TN (with additional requirements)
Assumed previous knowledge	5APA0: 5ECB0 or 5XCA0, 5EWA0 5EWB0 (for major AT students): 2DE20, 5ATA0, 5XCA0 5XWG0: 5ECA0, 5EWB0 5XWA0: 5ESB0, 5EWA0, 5EWB0
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Content and composition

The coherent package Electrical power conversion and delivery aims at designing, realizing and validating technologies to create electrical networks and electro- physical devices for transporting and manipulating electrical energy in a flexible, controlled, and sustainable way regarding efficiency of costs, power, and materials. The focus lies on intelligent power networks (Smart Grids), smart actuators and the reduction of pollution and waste. Quite some conditions have and will continue to reshape the energy supply system, such as the required introduction of renewable, but also less-predictable and less-controllable power sources (e.g., solar, wind, micro-turbines), market liberalization for electric power with (partly) price-sensitiveproducers and consumers and the arrival of plug-in hybrid and full electric vehicles. Any centralized strategy to assess stability, let alone optimality of such a huge, complex, connected system will fail. Still, the question remains how to cope and control such a connected system with hundreds of millions of active and only partly predictable prosumers (producer and/or consumer) and guarantee, each point in time, a balance between production and consumption, when only very limited storage capacity of electric energy is available, and any large-scale disturbance brings society to a hold with billions of Euros losses.

For students of the major EE:

Course code	Course name	Level classification
5APA0	Power electronics	2, deepening
5XWG0	Power system computation and simulation	3, advanced
5XWA0	Power system analysis and optimization	3, advanced

The preferred order for students to follow the courses is as stated above: first 5APA0, second 5XWG0, and third 5XWA0.

For students of the major AT:

Course code	Course name	Level classification
5EWB0	Electrical power systems	2, deepening
5XWG0	Power system computation and simulation	3, advanced
5XWA0	Power system analysis and optimization	3, advanced

The preferred order for students to follow the courses is as stated above: first 5EWB0, second 5XWG0, and third

5XWA0.

For students of other majors than EE and AT:

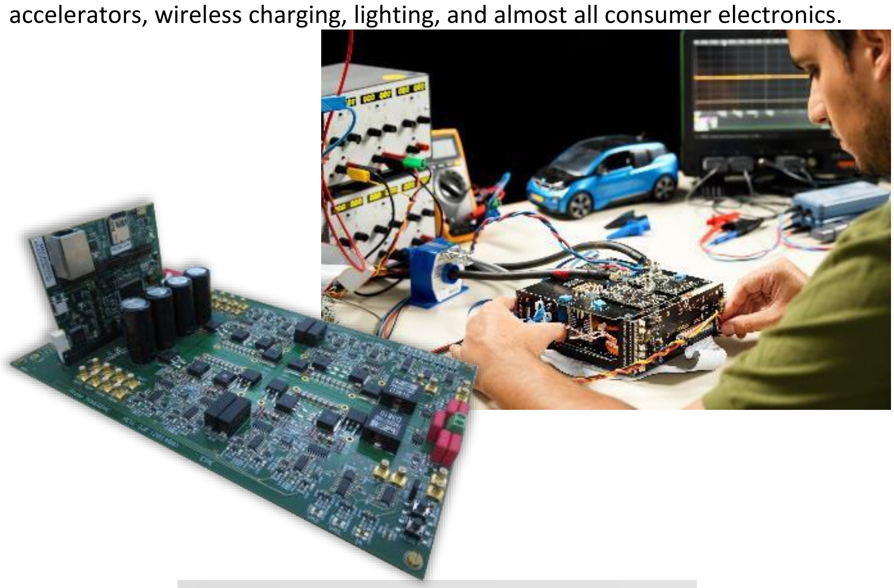
Course code	Course name	Level classification
5EWB0	Electrical power systems	2, deepening
5APA0	Power electronics	2, deepening
5XWA0	Power system analysis and optimization	3, advanced

The preferred order for students to follow the courses is either 5EWB0 or 5APA0 first, and 5XWA0 last.

Course descriptions

5APA0 Power electronics

This course treats the concept of switched-mode power conversion, or power electronics. This basic building block is found in most electrical applications and is used to convert between different voltage and current levels or to convert between DC and AC. Power electronic converters provide a way to adapt voltage and current to a form required by a specific load at a very high efficiency. Some application areas of these converters are battery chargers, connection of renewable sources to the grid, motor drives, audio amplifiers, medical equipment, particle accelerators, wireless charging, lighting, and almost all consumer electronics.



The lectures start with an introduction to the field of power electronics. Next, the converter topologies that are used in several applications are discussed, including DC-DC converters, inverters, diode rectifiers and phase-controlled rectifiers. These converters are analyzed based on steady-state behavior. Besides the lectures, a substantial part of the course is dedicated to gaining practical experience with power electronics during lab sessions.

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The learning goals of this course are:

- Obtain knowledge of and insight into the basic principles of switched mode power converters and their application.
- Understand the concept and operating principle, characteristics and application of DC-DC converters, inverters, diode rectifiers and phase-controlled rectifiers. Understand the operating principle characteristics and application of DC-DC converters, inverters, diode rectifiers and phase-controlled rectifiers.
- Analyze power electronic converters by means of calculations and computer simulations using simplifying assumptions (steady-state behavior, small-ripple approximation, ideal switching behavior and lossless components).
- Distinguish the conduction mode of a power converter, either from given converter parameters, or from graphs of voltage and current waveforms, and accordingly use the appropriate method for analysis
- Select the appropriate method of calculation of currents and voltages and their harmonic components in power converters
- Measure important quantities and characteristics on an experimental setup and explain differences between measurements and analytical calculations or simulations.

5XWA0 Power system analysis and optimization
There is no doubt that the use of electricity is intrinsic to our daily lives. But what does it take to deliver electrical energy where and when it is needed in a reliable and economically efficient way? This course takes a peek at the complex system that lies behind the socket! This course describes the principles of power system modeling, analysis, and optimization. More specifically, the topics covered in the course are: fundamentals of electrical power generation, transmission and distribution, power flow, symmetrical faults, asymmetrical faults, power system protection, transient stability, voltage control, frequency control, economic dispatch, unit commitment, optimal power flow, and electricity markets.

The learning goals of this course are:

- Identify the key-problems in electric power systems pertaining different parts and time-scales.
- Classify power system problems as steady-state or transient.
- Compute power flow solutions and compare the results obtained using different techniques.
- Analyze power systems under symmetrical and asymmetrical faults.
- Evaluate and design power system protection schemes.
- Evaluate the transient stability of power systems.
- Explain the principles of voltage and frequency control.
- Apply optimization techniques to solving electric power system problems.
- Outline the fundamental structure of electricity markets.
- Use both off-the-shelf simulation software and develop own computer code in order to solve analyze transient and steady-state problems of electric power systems.

5XWG0 Power system computation and simulation
During the energy transition, the smart grid concept is being brought to medium voltage (MV) and low voltage (LV) distribution grids to cope with the increasing penetration of renewable energy sources, electrical vehicles, heat pumps, etc.

Due to the high degree of the uncertainties in the grids, statistical methods and relevant data science technique are usually applied in the design and the operation of smart grids. To face this challenge, the energy sector needs people with a multidisciplinary profile including a combination of electrical power engineering, data science, and scientific software engineering.

Traditionally the distribution grid analysis is executed by experts using commercial power system simulation software using the graphical user interface (GUI). There are built-in scenario analysis tools in the software to analyze different scenarios, e.g., a time-series load profile. The result of an analytics work is usually a report with result data in appendices. Further actions based on the analysis are carried out.

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The trending workflow of distribution grid analysis relies on automation of the (deterministic and stochastic) calculations. The work begins with physical modelling using electrical power engineering knowledge. The commercial software is also often used here, but it is usually integrated as a software library instead of the GUI. In the mathematical modelling step the numerical computing and data science (statistics, machine learning, etc.) techniques are applied to solve the physical problem. In the end the solution has to be implemented in a mature software in automated systems. This workflow is increasingly popular in the energy sector because it can coup with all kinds of tailor-made demands on certain analytics problems and can be easily automated in a production environment.

This is an OGO course (project), done in teams, with the task of completing two assignments of simulating real-world problems in Power systems.

The learning goals of this course are:

- Introduction to power system modelling.
- Basics of numerical computing and its application in power systems.
- Basics of statistics and data science.
- Basics of data modelling.
- Introduction to scientific software engineering
- Common libraries for numerical computing and data science
- Common libraries for power system analysis
- Principles of testing
- Basics of modern collaboration tools in software development
- Version control
- Continuous delivery/integration
- Analysis of power flows and voltage levels.
- Analysis of system reliability and redundancy.
- Analysis of transport losses and the impact of system configuration.
- Impact of Electrical Vehicle charging on the Power System Infrastructure.

5EWB0 Electrical power systems
Almost every electrical engineer may face aspects of electricity supply. This course deals with basic concepts and components for the generation and transmission of electricity as well as basic calculation methods. Apart from basic principles, the course has the following core contents: conventional generation and control of electrical power, components in electrical power systems, network calculations and protection, and renewable generation of electricity.

The learning goals of this course are:

- To obtain knowledge of the fundamentals of power generation and electrical supply systems and their components.
- To obtain knowledge of the methods to study voltage patterns, power losses and power flows in electricity supply systems.
- To discuss the effects of renewable energy systems on our electricity supply system.