### Sustainability and Energy Business

**Energy Production, 5 ECTS**

**Course Code:** SATE202

**Description:**
- **Prerequisites:** Sähköenergiatekniikan perusteet is recommended
- **Objectives:** to get a rough view of the global possibilities of technology for energy sector now and in future. Course develops written skills (reading, writing).
- **Content:** global challenges and their implications for the energy sector, energy use, energy conservation technologies, energy resources, supply systems and scenarios on energy futures
- **Study Materials:** Energy Visions 2050, VTT Edita, 380 pages, copies of the book are available in Tritonia Library
- **Teaching Methods:** introduction lectures (4 hours) are given twice a year, an English exam, including the answering in English, detailed information via the WebOodi system for the registrated students
- **Modes of Study:** exam in English
  - **Languages:** language(s) of instruction: English; completion language(s): English

### Introduction to Renewable and Sustainable Energy, 5 ECTS

**Course Code:** ISAN2020

**Description:**
- **Prerequisites:** students are expected to be familiar with the basics of sustainable development and renewable energy types.
- **Objectives:** to help students to identify the types of renewable energy sources, to design and audit these various types of renewable energy sources and its role in the supply chain model of renewable energy and energy efficiency. The idea is to help identify how each local setting can be sustainable by relying on the types of renewable energy available to them.
- **Content:** renewable energy technologies, heat production technologies, technologies for producing electricity, CHP technologies.
- **Study Materials**
  - Scientific Articles
  - Supplementary Material Provided by the Teacher
### Teaching Methods
- Lectures and exercises 30 h, independent work 105 h

### Modes of Study
- Flipped learning, group report, written exam

### Languages:
- Language(s) of instruction: English
- Completion language(s): English

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**Battery Energy Storages in Smart Grids, 5 ECTS**

**Course Code:** SATEB2010

**Description:**
None

**Objectives:**
After completing the course, the student is able to understand reasons for power system changes, impact of these changes and need for utilization of flexible resources like battery energy storages to manage the impacts. The student will understand the key role of battery energy storages in the future power system in which more flexibility and controllability will be needed at all voltage levels. In addition, the student will gain strong knowledge about basics of battery technologies their modeling and management and overview of battery storage solutions in Smart Grids, smart homes and hybrid power plants. In addition, the course will cover topics related to electric vehicles effects on Smart Grids and multi-objective management of batteries in future power systems. Course exercise(s) will enable student to obtain in depth understanding related to some relevant battery storage topic.

**Content:**
Introduction to Smart Grids, Basics of Battery Technologies, Modeling and Management of Battery Energy Storages, Overview of Other Energy Storage Technologies for Smart Grids, Overview of Battery Energy Storage Solutions in Smart Grids, Energy Storages in Microgrids, Battery Storage Solutions for Smart Homes, Hybrid Power Plants with Battery Energy Storages, Electrical Vehicles Effects on Smart Grids, Multi-Objective Management of Battery Energy Storages in Future Power Systems

**Lectures (20h):**

1. **Introduction to Smart Grids, Hannu**
   - Traditional power systems (components, operation principles, dynamics)
   - Reasons for power system changes, impact of these changes, role of grid codes in managing the impacts, need for utilization of flexible resources like battery energy storages to manage the impacts
   - Characteristics of future smart and flexible power systems

2. **Basics of Battery Technologies, Chethan & Joel**
   - Traditional battery technologies (Lead-acid, Ni-Mh etc.)
   - Introduction to lithium-ion batteries (operation principle and main components of a lithium-ion cell, positive electrode materials, negative electrode materials, other components like electrolytes and separators)

3. **Modeling and Management of Battery Energy Storages, Chethan**
   - Modeling principles of lithium-ion batteries, dynamics, state estimation (SOC, SOP, SOH, temperature), charging/discharging control, cell balancing control, temperature control, safety and protection principles/solutions for batteries, battery management system

4. **Overview of Other Energy Storage Technologies for Smart Grids, Omid**
   - New battery technologies, metal-air (zinc-air), vanadium redox-flow batteries, sulfur-flow-battery, ultra-/supercapacitors, hybrids (battery with supercapacitor), power-to-gas, hydrogen-based fuel-cell storages, flywheel, superconducting magnet, compressed-air, thermal energy storages (heat storages)

5. **Overview of Battery Energy Storage Solutions in Smart Grids, Chethan**
- Potential of battery energy storages to participate in providing different technical services locally and system-wide
- Use of second-life batteries from electric vehicles in grid applications, which kind of grid applications are most suitable for second-life batteries- Grid-scale centralized / de-centralized solutions at HV/MV and MV/LV substations
- Hybrid Power Plant solutions (battery + gas-based combustion engine, battery + PV plant, battery + wind turbine/park)
- Consumer scale hybrid solutions (Battery + PV + EV) in Smart Homes
- Microgrid solutions

**6. Energy Storages in Microgrids, Omid**
- Different kind of microgrids including also e.g. traditional back-up power/UPS based microgrids for hospitals and datacenters etc.
- Management and control principles (centralized, decentralized, hierarchical etc.) of different possible energy storages in microgrids
- Role of battery energy storages in AC, DC- and hybrid microgrids during grid-connected and islanded operation
- Microgrid management, microgrid controller functionalities and related standardization, control of batteries as part of microgrid management (grid-connected and islanded mode), role of weather and other forecasts
- Fault management / behavior and effect on protection during grid-connected and islanded modes

**7. Battery Storage Solutions for Smart Homes, Visiting lecture- Visiting lecture / (Helen)**

**8. Hybrid Power Plants with Battery Energy Storages, Visiting lecture- Visiting lecture / (Wärtsilä, VEO, Danfoss)**

**9. Electrical Vehicles Effects on Smart Grids, Hossein**
- State-of-the-art of electric vehicle (EV) technologies (charging technologies for passenger cars, buses, other types of vehicles, battery technology in EVs)
- EVs in smart grids (charging load of EVs in distribution networks, EVs potential to provide technical services locally and system-wide in future smart grids)
- Vehicle-to-Grid (V2G), Vehicle-to-Home (V2H) solutions
- Consideration of EV future charging solutions in network planning

- Batteries have potential to provide technical services locally and system-wide for multiple purposes
  - How this multi-use capability and capacity should be optimally used under different constraints (considering issues related, for example, to regulation/legislation, market and business models, technical limits, battery lifecycle)?
  - Role of different forecasts (weather, market, flexibility)
- Aggregator, flexibility operator, virtual power plant (VPP) and multi-microgrid concepts with battery energy storages
- Consideration of battery energy storages (first and second-life) in future long-term planning of MV and LV networks

**Topic(s) for written exercises:**
- Second-life Battery Storage Applications in Smart Grids
- Possibilities of Big Data Analytics and Optimization in Battery Storage Applications for Smart Grids
- Battery Storages and Resilience of Smart Grids- Future Grid-Scale Battery Energy Storage Technologies

**Simulation exercises (later, not included in the pilot version of the course)**
- With PSCAD and/or Matlab

**Study Materials**
Lecture material (and other material announced in lectures)
C Programming, 3 ECTS

Course Code: ICAT1010

Prerequisites: TITE1070 Programming or ICATC1050 Introduction to Programming or respective course which covers the principles of programming, this course is targeted to students without prior knowledge of C.

Objectives: This course aims to teach the skills necessary for the development of C applications. After completing this course the student will be able to develop C programs containing simple data structures. The student will learn how to implement programs according to given or own developed flowcharts. Also the use of debuggers will be introduced and applied. The skills learned in the lectures must be applied in the exercises.

Course develops lifelong learning, oral; written and interpersonal skills (Group Work, English), critical and analytical thinking, problem modeling and solving skills, IT skills and optimized decisions.

Content: In the lectures the theoretical parts required for the exercises are presented. To the course contents belong data types, conditions, loops, arrays and pointers, macros, static and dynamic allocation, structures, time handling and file handling. The exercises contain the development of C/C++ applications related to the previously mentioned course contents.

Study Materials: lecture slides and course book

Teaching Methods: lectures 16 h and exercises 16 h, independent work 46 h

Modes of Study: lectures, practical exercises, and final examination

Languages: English (lectures and exercises)

Artificial Intelligence in Energy technology, 5 ECTS

Course Code: ICAT2090

Description:

Prerequisites: Basics of Programming OR Introduction to Programming, in addition Object Oriented Programming is recommended

Objectives: After completing this course the student will be able to explain and model uncertain information, the principles of fuzzy logic; explain the principles of fuzzy reasoning; describe the most important energy applications and application areas of fuzzy logic; apply the principles of fuzzy sets theory; fuzzy rules and fuzzy control; explain the principles of neural networks; describe the most important neural network types; apply learning of neural networks; describe the
### Content
- most important energy applications of neural networks; describe the principles of evolutionary computation; apply the principles of multiparameter optimisation; describe the principles of global optimisation; describe the typical energy applications of genetic algorithms; implement an application of genetic algorithms; combine and apply different soft computing methods; design, implement, test and document a simple soft computing application. Terminology in Finnish and in English.

Course develops verbal representation (lecture), literal representation (documentation in English with Finnish abstract), cooperation skills (group lecture and labwork), lifelong learning (critical search for information and analysis), it skills (problem solving by programming and computing).

### Study Materials
- lecture notes and materials

### Teaching Methods
- lectures 20 hours, exercises 20 hours, project work 20 hours, independent work 72 h

### Modes of Study
- exam (ICAT 2091 3 ECTS) and project work (ICAT2092 2 ECTS)

**Languages:** language of instruction: teaching Finnish / exercises English; completion language(s) English

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### Energy Efficient Digital Signal Processing, 5 ECTS,

**Course Code:** ICAT1040

**Description:**

- Prerequisites: Basic of programming and Basics of digital electronics
- Objectives: after having passed the course the student is able to:
  - Describe the structure of an energy efficient digital signal processing system, design, implement and test the most common simple signal processing methods used in energy efficient signal processing by programming with e.g. Matlab.
  - Course develops literal representation (read and write signal charts), critical thinking and analysis (analyse mathematically and numerically discrete signal processing methods, apply the most common signal processing methods) and life-long learning (search information on signal processing methods and their applications).
- Content: most common filters, discrete signals and systems, Z transform, flow charts, Fourier and Laplace transform, FFT, design of energy efficient filters and finite numerical precision, energy efficient filter: design of FIR-filter by IRT method, DSP application in energy technology with e.g. Matlab and JavaScript on web.
  3. other material announced on lectures
- Teaching Methods: lectures 20 h, exercises 20 h, independent work 41 h
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