SUSTAINABLE POWER GENERATION (SPG)
MJ2405

Syllabus

Availability: Conditionally elective. Compulsory for several MSc programs.
Language of instruction: English
Level: Second cycle (1st year of MSc or 4th year of BSc studies)
Study Credits: 9 ECTS (1.5 + 1.5 + 6)
Taught during: Autumn term (September-December), every year

Hosting Institution:
KTH Royal Institute of Technology,
School of Industrial Engineering and Management (ITM),
Department of Energy Technology (EGI),
Division of Heat & Power Technology (HPT),
campus Valhalla - Mechanical Engineering Quarter (M),
Brinellvägen 66-68, Stockholm, Sweden

Course Coordinator: Miroslav Petrov = *Miro*
Teachers and instructors: Miro + affiliated professors + guest lecturers
Examiner: Miroslav Petrov

Introduction

The SPG course provides a comprehensive overview of the most vital power generation technologies related to both conventional and alternative fuels for the production and distribution of electricity and heat. The focus is on thermal power; specifically, on the system's perspective and thermodynamic cycle design of thermal power plants, regardless of the type of fuel.

SPG belongs to a unified block of first-term MSc-level courses, running in parallel and logically integrated regarding their focus and contents:

- Sustainable Power Generation (SPG) MJ2405;
- Sustainable Energy Utilization (SEU) MJ2407;
- Renewable Energy Technology (RET) MJ2411;
- Energy & Environment (E&E) MJ2413.

These courses are interrelated and complement each other. Together, they cover the whole spectrum of necessary fundamental knowledge on energy conversion, heat and power generation, renewable energy sources, conventional and alternative fuels, pollution prevention and emissions reduction, refrigeration and energy utilization in the built environment, energy policies and system planning, global issues of geopolitics, human development and climate change.

The sustainability aspect of the SPG course is closely linked to the other three courses as described above, where certain material belonging to the SPG topic is

instead offered by the RET, SEU or E&E courses. All students joining the SPG course are advised to enrol also in the other three courses if pursuing a broader overview on sustainability or if specialising in energy- or environmental engineering.

Prerequisites

A solid understanding of classical thermodynamics is desired, as well as basic physics and chemical process technology.

Course Structure and Contents

The SPG course can be divided into two consecutive sections. The first one covers period 1 (September-October) and is more intense, containing both theory lectures and calculation exercises/homework tasks; while the second part of the course continues through period 2 (November-December) and is composed only of theory lectures.

The **first section** focuses on fundamental understanding of thermodynamic cycles, energy conversion and energy balance, and on the major building blocks of the primary technologies for thermal power generation regardless of fuel type:

1) *Combustion Reactions for hydrocarbon fuels;*
2) *Boilers and Furnaces;*
3) *Steam Cycles and Steam Turbines;*
4) *Gas Turbine Cycles;*
5) *Combined Gas & Steam Cycles.*

These five major topics are treated on introductory level but in enough detail to give a good understanding of the foundations of classical thermodynamics applied to thermal power cycles and of the conventional technologies for energy conversion in modern power plants, as well as the methods to improve their efficiency and to decrease their environmental footprint.

Each of these five main topics is introduced and reviewed during a:

- ✓ Classroom Lecture on theoretical background;
- ✓ Tutorial in class on an illustrative calculation exercise;
- ✓ Calculation homework task (home assignment) similar to the tutorial;
- ✓ Theory quiz in a multiple-choice format, as a theory homework task.

Thus, there are 5 different calculation home assignments and 5 theory quizzes in the first section of the course, as per the topics above. They all are required as mandatory deliverables towards completion of the course, see further below.

The **second section** of the SPG course contains only theory material in the form of classroom lectures. The topics span over power plant layout and auxiliary equipment, turbine design and operation, piston engines for power generation, innovative energy conversion technologies, energy economy and system planning, conventional fuel production & exploration, CO2 separation and sequestration, and also including an introduction to nuclear power and an overview of both conventional fission and future fusion nuclear reactors.

Learning Objectives and intended learning outcomes

The SPG course is building upon topics fundamental to energy engineering, and is attempting to provide a deeper insight into the main issues related to technology improvements for efficient energy conversion via thermal processes. A switch from fossil-based to renewable energy is not a sustainable solution by itself, unless system stability and utilization strategies are properly planned and the efficiency of energy conversion continuously improved.

The main purpose of the SPG course is to prepare the students for subsequent specialization in their chosen fields. The SPG course cannot provide exhaustive knowledge on all aspects of power engineering. The large number of participants from various backgrounds puts a limit on the scope and depth of the SPG course.

After a successfully completed course, the students would be able to:

- ✓ Master the principles behind the major technologies for thermal energy conversion and power generation, both conventional and renewable;
- ✓ Possess a broad knowledge base for the proper design and assessment of modern power generation systems;
- ✓ Identify the layout and the main components of various thermal power cycles;
- ✓ Calculate the overall energy balance of thermal power generation cycles regardless of the type of fuel or working media;
- ✓ Analyse thermal power systems thermodynamically and economically;
- ✓ Perform a quick environmental assessment of thermal power technologies;
- ✓ Evaluate combustion parameters and boiler performance;
- ✓ Compare different power generation alternatives and select the most optimal one for the given conditions, relying on basic parameters;
- ✓ Suggest and justify possible efficiency improvements!

Literature

The SPG course covers a broad overview of technologies. A typical obstacle is that there is no perfectly applicable book that can be used as a single course material.

Any book on applied thermodynamics and/or energy conversion would contain some relevant study material. There are hundreds of textbooks or web-based sources that could be useful for parts of the topics taught in the course!

The most recent textbook that contains material relevant to the SPG course, offering the best match concerning scope and depth, is the following:

1) **ADVANCED ENERGY SYSTEMS, 2nd Edition**; Nikolai V. Khartchenko & Vadym M. Kharchenko; *CRC Press*, 2014. ISBN: 9781439886588
http://www.crcpress.com/product/isbn/9781439886588

This book is not available for free, alas. It can be purchased directly from the publisher or from the KTH student literature shop (in the student union building, KTH campus).

*A selection of **some generally recommendable textbooks**, available for purchase in paperback format from online shops or possible to borrow in libraries:*

2) Moran, M. J. & Shapiro, H. N. "Fundamentals of Engineering Thermodynamics, 3rd edition", 1998.
3) R. Kehlhofer, "Combined Cycle Gas and Steam Turbine Power Plants".
4) Elliot T.C. et al. "Standard Handbook of Power Plant Engineering, 2nd ed.",1997.
5) Decher, R. "Energy Conversion: Systems, Flow Physics and Engineering", *Oxford University Press,* 1992, ISBN: 0-19-507959-0.

***Freely available e-book** on the web (not perfect but good enough for some topics):*

6) Kenneth C. Weston, "**Energy Conversion**" – online open-access at: http://www.personal.utulsa.edu/~kenneth-weston/.

*Good **e-books** that can be **partially useful** for the SPG course, **freely accessible** via the KTH Library online resources (only through a KTH student account!):*

7) **Thermodynamics;** by Enrico Fermi, *Dover Publications,* 1936 – on www.knovel.com
8) **Introduction to Thermodynamics;** by Keith Sherwin, *Springer,* 1993 – on www.link.springer.com
9) **Engineering Thermodynamics;** Dwight C. Look Jr., Harry J. Sauer Jr.; (SI-edition by Graham Alexander) 1988 – on www.link.springer.com
10) **Thermodynamics - Foundations and Applications;** Gyftopoulos, Elias P.; Beretta, Gian Paolo; *Dover Publications,* 2005 – on www.knovel.com
11) **Combined-Cycle Gas and Steam Turbine Power Plants** (3rd Edition); Kehlhofer, Rolf; Rukes, Bert; Hannemann, Frank; Stirnimann, Franz; *PennWell Publishers* – on www.knovel.com
12) **Carbon Capture and Storage;** Rackley, Stephen A., *Elsevier*. – on www.knovel.com
13) (translated from French): **CO2 Capture - Technologies to Reduce Greenhouse Gas Emissions;** Lecomte, Fabrice; Broutin, Paul; Lebas, Etienne; 2010 – on www.knovel.com
14) **Renewables-Based Technology - Sustainability Assessment;** Dewulf, Jo; Van Langenhove, Herman (editors); *John Wiley & Sons*. – on www.knovel.com
15) **Power Plant Life Management and Performance Improvement;** Oakey, John E. (editor), *Woodhead Publishing*. – on www.knovel.com

For the Swedish-speaking students:

16) **Tillämpad termodynamik;** Ingvar Ekroth, Eric Granryd; *Studentlitteratur*
17) **Energilära – grundläggande termodynamik;** Olof Beckman, Göran Grimvall, Bengt Kjöllerström, Tage Sundström; *Liber AB,* 2005.
18) **Energiteknik** (Del 2)**;** Henrik Alvarez; *Studentlitteratur,* utgåva 2006.

Quick reference material on the web:

19) **CompEdu** – a freely accessible web-based educational compendium containing condensed presentations and interactive study material on many topics in the field of energy engineering. Good for a quick check! (http://www.energy.kth.se/compedu/webcompedu/WebHelp/index.html)

Course management platform:

KTH has recently undergone a switch to a new Online Learning Management System (LMS) based on the international software platform **CANVAS**, owned and distributed by Instructure. CANVAS is accessed through your KTH student account via the main KTH webpage log-in gate, or directly at https://kth.instructure.com.

The SPG course aims at actively utilizing the CANVAS platform as much as possible for distributing course material such as lecture notes & videos, tutorials, exercises and quizzes, additional literature, announcements & mass-messaging.

"KTH-Social" or other social media sites shall **not** be used in this course.

Examination & Grading

Student performance is evaluated at several occasions throughout the SPG course. Continuous involvement in studies and exchange of knowledge among students are encouraged. The course makes use of four different types of tests and exams:

1) **Mid-term submittal of calculation homework tasks (ÖVN1), 1.5 ECTS.**
   The homework submittal targets directly the 5 home assignments from the first section of the course, whose solutions should be uploaded online in CANVAS with 100% correct answers. The specific calculation tasks and any additional information will be gradually rolled out as the course proceeds.
   The homework submittal gives 1.5 credits, appearing as "ÖVN1" or "Exercise1" in the formal transcript.

   Grading: pass or fail (P / F).
   Deadline for quick credit transfer: Midnight of October 25th, online in CANVAS.
   Homework submittal is also possible anytime later, without any effective deadline! However, the credits will take very long time to appear in the transcript.

2) **Theory Quiz submittal at the end of the course (ÖVN2), 1.5 ECTS.**
   A series of theory quizzes in a multiple-choice question format (MCQ) will be made available in CANVAS, covering all topics taught and gradually rolled out as the course proceeds throughout the end of the term.
   Completing all theory quizzes at 100% correct answers provides 1.5 credits, appearing as "ÖVN2" or "Exercise2" in the formal transcript.

   The theory quizzes as well as the calculation homeworks remain open also after the end of the course. They can all be attempted anytime, for unlimited number of attempts until passed with 100% correct answers.

   Grading: pass or fail (P / F).
   Deadline for quick credit transfer: Midnight of December 18th, in CANVAS.
   Any later submittal is possible, but then the credits will be registered with a large delay, typically long after the final exam in 2018.

3) **Mid-term Calculation Exam (Control Test)!**
There is a major control test in the SPG course, to be performed in exam-like conditions on October 26th, 2017, starting at 08.00 a.m. sharp.

The test is only about calculations, where 4 calculation tasks should be solved within 4 hours. The specific tasks are based on the exercises and homeworks from the first section of the course and offer an exam-style challenge.

The control test is an open-book exam where all help materials in any format is allowed, with the only exception of mobile phones or communication tools. Any support on paper or in digital format can be used, including books, printouts, solved examples, online resources, own laptops, etc. If using a calculator, it can be in any format but should be a standard device, not a mobile phone.

The control test is performed in computer rooms on campus, with free access to the internet during the entire exam. However, physical presence is required in the allocated room, with a strict ID-check.

The control test is not directly linked to credits. It is graded in terms of points (carrying a total maximum of 50 points) which selectively can be used towards replacing the calculation part of the final exam, see further below.

The control test is not compulsory and not crucial for passing the course, but offers a valuable training and the opportunity to use the collected points towards waiving off the calculation tasks at the final exam.

4) **Final Exam, 6 ECTS.**
The main exam for the SPG course consists of a theory part and a calculation part, for a total of 5 hours. This academic year the exam is scheduled on two different days: December 19th, 2017; and January 11th, 2018; both starting at 08.00 a.m. sharp. Each student has a free choice to decide on which of these two occasions to sit for the exam (one of them only), depending on personal preferences or on any other factors related to schedules or travel plans.

The exam demands personal presence and identification. The seating is in computer rooms on campus. Again, it is an entirely open-book event where all possible help material and any help tools are allowed, both in paper form and electronic. The only forbidden things are mobile phones of all sorts and any communication tools.

a) **Theory part** – takes 1 hour and contains a blend of quiz-style multiple-choice and open-ended essay questions covering the entire spectrum of course material from all lecture topics.

b) **Calculation part** – takes 4 hours and contains 4 calculation tasks. The arrangement of the calculation part corresponds closely to the mid-term calculation exam.

Each part of the final exam carries 50 points, summing up to a total of 100. If the summed points from the calculation tasks are below 25, the student fails the entire exam and is welcome to try again at the subsequent re-exam occasions.

The points gained at the mid-term exam (control test) can be used to replace the calculation part of the final exam – for each corresponding calculation task. If the calculation part of the final exam is entirely replaced by control test points, the student sits only for the theory part, in such case only 1 hour.

The exam is graded from F to A in an absolute scale. The different grades are directly linked to thresholds of collected points, subject to adjustments:

Points:	→	***Grade:***	***grade interpretation:***
0 - 46		**F**	Firmly Failed (or if <25 on calculations)
47 - 48		**Fx**	Eligible for E after additional task
49 - 54		**E**	Passes with minimum
55 - 67		**D**	Passes at average
68 - 79		**C**	Passes satisfactory above average
80 - 90		**B**	Passes with distinction
91 - 100		**A**	Passes with honours

The final grade from the SPG course is the same as the exam grade. However, all parts of the course should be passed (all credits obtained) in order to get a final grade and complete the entire course.

The re-exam is a repetition of the main exam and is expected to be scheduled for March-April 2018. The specific day and time will be decided by the administration during the winter.

Administrative issues

The course teachers are not able to help with computer accounts, registration, access to CANVAS or concerning administrative questions at KTH. If such problems occur, the student is advised to turn directly to:

- ✓ *ITM Student Reception/Expedition Office at the entrance of Brinellvägen 68* – for general questions about administration and transcripts, course enrollment or delayed registration, enlisting for exams, etc.

- ✓ *MSc program director* – if you belong to a MSc program group, most issues should first be discussed with the director of your program.

- ✓ *KTH International Office* – if you are an exchange student, most issues should first be discussed with your contact person at the International Office.

- ✓ *Central IT-support at KTH (called "Mimers Bar") in the student union building* – for problems with your computer account or email address at KTH. The personal accounts are created and serviced only by the central IT support.