KTH Electrical Engineering

Course program P4 2024 18/03/2024

EI2452 Reliability Evaluation of Electrical Power Systems (7,5 hp)

Learning Outcomes

The course main goal is the skills of using reliability analysis as a tool for decision support for planning and operation of electric power systems. After the course completion, the participants are expected to achieve the knowledge and skill to:

1. Describe the fundamental definitions and concepts for reliability assessment
2. Analyze a system and its components using the following techniques for reliability assessment:
    - network modelling for the analysis of systems of independent components (including effect of redundancy),
    - methods for identification of component importance,
    - Markov modelling,
    - lifetime models
3. Analyze an electrical distribution system with the above-described methods with tools such as, e.g., NEPLAN
4. Describe how reliability is treated in the regulation
5. Carry out a life cycle cost analysis LCC (Life Cycle Cost)
6. Integrate sustainability and resilience impact in asset management decisions.
7. Formulate a reliability centred maintenance plan following so called Reliability Centered Maintenance, RCM, and give an account of the more advanced method Reliability Centered Asset Management, RCAM.

in order to be able to use reliability analysis as a tool for decision support at development, operation and maintenance of electric power systems.

The learning outcomes 1-2 are tested mid-course in the exam of the second teaching part. Goal 3 and 5 are fulfilled when successfully participating in the practical laboratory sessions. The learning outcomes 3-6 are tested in the home-exam together with some more advanced parts of 1 and 2. 1-7 are also examined in the project assignment. In addition, the students will acquire advice and practice in reporting, reviewing, giving feedback, and presentation technique.

Course outline and activities

The workload of the course corresponds to 5 weeks fulltime studies (200 h – 7.5 hp) during period 4. The teaching is organized in 3 course parts of 2-3 days each and a final presentation session of 1 day. In particular, the course parts include the following activities:

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- **Registration:** The students must register for the course via e-mail to the course responsible (zhonli@kth.se) until the end of the first course part or sign the enrolment list which is available during the lectures of the first course part.
- **Lectures and video lectures** present different reliability methods and topics. The teaching focuses on the theoretical background as well as the applicability towards power systems. The lectures include exercise sessions and group discussions are stimulated. Video lectures can be discussed and clarified through online forum discussions (Canvas).
- **Guest lectures** by invited speakers with industry background who talks about the practical viewpoint of reliability analysis. The speaker presents theory as well as experience gained during planning, operation, and maintenance of power systems.
- **Exam** tests the elementary knowledge of the methods presented in the course part 1. A high degree of the answers has to be correctly answered to pass the exam (80% range). A high grade in the exam will positively influence the overall grade of the course, see section examination and grades.
- **Home assignment** is a written examination of knowledge up to the second course part. More information can be found in section examination and grades.
- **Laboratories** are practical exercises to apply the methods and tools taught in the course. The participation in these exercises is mandatory and a written report needs to be handed in after both sessions. The sessions are executed in pairs of two students.
- **Seminar** includes the oral presentation of the performed projects and their reports of every student. The participation is mandatory, see section examination and grades.
- **Conducting the project assignment:** The project has to be executed individually or in groups of two. The investigated problem should be a concrete and practical case which could be related to the students current work from a reliability analysis viewpoint. Where applicable it is recommended that the student select a project from his/ her professional background, which could also result in a master thesis project or a scientific publication. The initial project description is formulated before part 2 of the course. The work on the project must be on a continuous basis within the course parts and in-between. The final project work will be presented in a seminar, including feedback from an opponent. The project report needs to be handed in before the final seminar.
- **Additional tasks (optional):**
    - **Create exercises:** Every participant has the opportunity to hand in one or more self-created exercises and solutions based on the course material before the 5th of June 2024. Depending on the quality, the participant can gain up to 2 grade_points extra (affecting grade).
    - **Identifying calculation errors** in the course material and presenting the correct solution will add 0.5 grade_points for each detected error and solution to the total grade_points.
    - **Maximal 2 course points** can be added to the overall grade_points from the two aforementioned tasks.

Course material

The course is based on the book:

1. Carl Johan Wallnerström, Patrik Hilber, “Reliability Analysis and Asset Management Applied to Power Distribution”, March 2014.

This book and further course material such as lecture and laboratory notes can be bought for 130 SEK during the course part 1 and 2. Other relevant course books are:

2. Roy Billinton and Ron Allan, “Reliability Evaluation of Power Systems”, 2nd edition.

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3. Rausand, M., Barros, A., and Høyland, A. *System reliability theory: models, statistical methods, and applications*. Wiley.
   (Remark: These books are not necessary for fulfilling the course requirements.)

Examination and Grades

Examination

To successfully finish the course, the following requirements must be fulfilled:

- Passing of the project assignment (PRO2) of 4.5 ECTS credits, which includes:
  - A passed written and oral presentation of the assignment.
  - Successful participation in the laboratories and handing in the lab report.
  - Participation at the seminar. This involves opposing another project assignment. Questions have to be prepared before the seminar and a half-written page of comments on the project report must be given to the defendant.
- Examination of the course content (TEN2) of 3 ECTS credits.
  The course content is examined in three parts:
  - **Qualifier questionnaire.** A Canvas questionnaire on the course work has to be answered prior to starting the written exam, the home exam as well as final presentation. This will primarily check that the teaching material (like online, video and live lectures) has been studied.
  - **Written exam**. The allowed tool during the exam is a calculator. Necessary formulas are given in the exam instructions. Registration for the exam is mandatory and must be done by sending an email to the course responsible zhonli@kth.se. The results are available latest one week after the examination date.
  - **Home exam**. All tools and resources are allowed. All sources and references except course book 1 have to be clearly stated. The support of the teaching staff is limited to the assistance of a normal written examination (e.g. if obvious flaws are identified, guidelines on how to handle these will be given).
    Remark. The problems in the home exam must be solved individually. Similar solutions will be investigated. However, it is recommended to have a dialogue with other students. The time to solve the home exams is approximated with two working days.

Grades

The overall grade in the course is a contexture of the grades on the different parts of the course (supposing that all the parts have been passed). Grades are given in accordance with the ECTS system (A-E, pass; Fx not passed but having a possibility to upgrade without taking the re-exam; F failed).

Maximum grade_points for each part are (0 = pass):

- Written examination 1p
- Home exam 2p
- Project assignment 3p
- Optional activities 2p

The grades are divided into the scale:

- < 1.5 E
- ≥ 1.5 D
- ≥ 2.5 C
- ≥ 4.0 B
- ≥ 5.5 A
- ≥ 7.0 A+ (a letter of recommendation will be offered)

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Submission of reports

The submission of reports and home assignments should be done directly or by e-mail to the course responsible or a course assistant. For the submission of the material are the following dates set:

- The project formulation must be formulated under course part 1 and submitted before course part 2 or the latest on **9th of April 2024**.
- The reports of the laboratories have to be submitted latest on **17th of April 2024** for laboratory 1 and latest on **30th of April 2024** for laboratory 2.
- The home exam assignment must be submitted by **17th of May 2024**.
- The project reports must be submitted by **22nd of May 2024**.
- The final version of the project report must be submitted by 5th **of June 2024**.

Deadlines

Material handed in before deadline will be evaluated within a reasonable time. This enables the opportunity for the student to make adjustments based on the given feedback, so that the course can be passed within the same period. Material handed in after deadlines can only achieve a pass with 0 grade_points. If a laboratory or project report is handed in after deadline, it will subtract 0.5 grade_points to the overall student examination score. Moreover, material handed in after the 9th **of June** will by the latest be handled/examined when the next course runs.

Contact information

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Course responsible: Zhongtian Li, zhonli@kth.se
Examiner: Patrik Hilber, hilber@kth.se
Teaching assistants
Sylvie Koziel, koziel@kth.se
Industry lecturers
Wadih Naim,
Sanja Duvnjak Žarković
Jan Henning Jürgensen,
Ebrahim Shayesteh,
Tommie Lindquist,

Course information

Course webpage: **http://www.kth.se/student/kurser/kurs/EI2452?l=en**

Course Feedback

After the students have successfully conducted the course parts and the project assignment, constructive feedback is welcome. Therefore, short feedback questionnaires are provided after the course. These include questions such as: What parts of the course were well executed and what could be done better (sorry no coffee will be available)? Did you learn new things and could that be applied to your (expected) profession? Suggestions on how to improve the course etc.

Schedule

The schedule for all course parts is presented in the following tables. The tables show the code, the lecture content, lecturer, rooms, time, and day. The code shows the type of session: lectures (F), guest lectures (G), exercise (Ö), project work session (P), laboratories (Lab), exams (TEN), and seminar (SEM). Lecturer names are abbreviated with: Patrik Hilber (PH), Sanja Duvnjak Žarković (SDZ), Jan Henning Jürgensen (JHJ), Sylvie Koziel (SK), Tommie Lindquist (TL), Wadih Naim (WN), Zhongtian Li (ZL) and Ebrahim Shayesteh (ES). The course rooms are all at the **KTH**, Main Campus, Stockholm and can be found here: http://www.kth.se/places .

Course part 1:

Code	***Content***	***Lect-urer***	***Room***	***Time***	***Day***
F1a	Course introduction	PH, All	Lindstedtsvägen 24, floor 5, room 522, Fantum	10-11	Tue 19 March
F1b	Introduction to the field of reliability analysis	PH	Lindstedtsvägen 24, floor 5, room 522, Fantum	11-12	Tue 19 March
F3	Introduction to Markov models	PH	Lindstedtsvägen 24, floor 5, room 522, Fantum	13-15	Tue 19 March
F4	Risk and vulnerability analysis	ES	Video lecture		Wed 20 March
F5	Markov models	ES	Video lecture		Wed 20 March
F6	Methods for power system analysis	ES	Lindstedtsvägen 24, floor 5, room 522, Fantum	10-12	Wed 20 March
F7	Failure models	JHJ	Video lecture		Thu 21 March
F8	Approximative methods for system analysis	PH	Video lecture		Thu 21 March
F9	Methods for analysis of the power grid and stations	ES	T 33, floor 3 room 2306, Ivar Herlitz	9-12	Thu 21 March
Ö1	Defining and preparing the project and Q&A session regarding course part 1	All	Lindstedtsvägen 24, floor 5, room 522, Fantum	13-15	Thu 21 March
Ö2	Exercise	ZL	T.B.D		

Own work between course part 1 and 2: formulation of the project assignment

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Course part 2:

Code	*Content*	*Lect-urer*	*Room*	*Time*	*Day*
TEN1	**Exam**	**ZL, All**	Lindstedtsvägen 24, floor 5, room 522, Fantum	10-12	Tue 9 April
F9	Asset Management	WN	Video lecture		Tue 9 April
F10	Economic analysis, introduction	JHJ	Video lecture		Tue 9 April
F11	Asset data and maintenance planning	WN	Video lecture		Tue 9 April
F12	Impact of Distributed Renewable Generation (DRG) and Electrification on Reliability	WN/SK	Video lecture		Tue 9 April
F13	Methods for reliability importance	PH	Video lecture		Wed 10 April
Ö3	Presentation of problem descriptions and Q&A session	All	T31, floor 3, room 1320, Gustaf Dahlander	11-12	Wed 10 April
Lab1	**Laboratory part 1:** Reliability analysis of the power grid - introduction and NEPLAN exercise	ZL	T33, Computer room, Frances Hugle	13-17	Wed 10 April

Own work between course part 2 and 3: work with project assignment.

Course part 3:

Code	*Content*	*Lect-urer*	*Room*	*Time*	*Day*
F14	Cost- and LCC-analysis	SK/ WN	Video lecture		Tue 23 Apr
F15	Introduction to Monte Carlo simulations	ES	Lindstedtsvägen 24, floor 5, room 522, Fantum	10-12	Tues 23 Apr
Lab2	Laboratory part 2: *LCC-analysis for the power grid with an example of an actual case study within RCAM*	ZL	TR33, Computer room Frances Hugle	13-17	Tue 23 Apr
F16	Methods for reliability centered maintenance	PH, ES	Video lecture		Wed 24 Apr
G1	Föreläsning: Tillämpad livslängdsanalys (guest lecture in)	TL, PH	Lindstedtsvägen 24, floor 5, room 522, Fantum	10-12	Wed 24 Apr
Ö, P	Theory recap & Project Work & Q&A	All	T31, floor 4, room 1411, Erik G Hallén	15-17	Wed 24 Apr
Re-exam	**Re-exam** – second opportunity to successfully pass the written examination.	ZL, All	T31, floor 4, room 1411, Erik G Hallén	15-17	Thu 25 Apr

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Code	*Content*	*Lecturer*	*Room*	*Time*	*Day*
TEN2	**Home assignment**	**All**	n/a	n/a	10-17 May

Own work before the last seminar: finishing the project report and preparing for the oral presentation and reviewing another student's report

Seminar:

Code	*Content*	*Lecturer*	*Room*	*Time*	*Day*
SEM	**Seminar**: oral presentation with questions from the reviewers and others	All	T 33, floor 3 room 2306, Ivar Herlitz	10-16	Wed 29 May

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