



KTH Electrical Engineering

Course program P4 2019

06/03/2019

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

## Learning Outcomes

The course aims to teach 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. Describe the distribution grid (including the protection system) from a reliability perspective.
3. Analyse a system using the following techniques for reliability assessment:
  - a) Network modelling
  - b) Component importance techniques
  - c) Markov modelling
  - d) Lifetime models
4. Conduct reliability calculations with tools such as NEPLAN.
5. Formulate a life cycle cost (LCC) model and conduct investment- and risk evaluations based on the results from reliability and LCC calculations.
6. Describe a reliability-based plan for maintenance control according to a reliability centred maintenance (RCM) strategy and gain knowledge about reliability centred asset management.
7. Describe the potential impact of laws and regulations on different parties within the energy distribution sector from a reliability perspective

The learning outcomes 1-3 are tested in the exam of the second teaching part. The goals 4 and 5 are fulfilled when successfully participating in the practical laboratory sessions. The learning outcomes 1-3, and 5-6 are also examined in an individual project assignment in the end of the course. Outcome 7 can be part of the final project report. In addition, the students will acquire advice and practice in reporting, reviewing, giving feedback, and doing presentations.

## Course outline and activities

The workload of the course corresponds to 5 weeks fulltime studies (200 h – 7.5 hp) during period 4 (March to May) 2019. The teaching is organised 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:

- **Registration:** The students must register for the course via e-mail to the course responsible ([sanjadz@kth.se](mailto:sanjadz@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** contain an invited speaker with an industry background who talks about the practical viewpoint of reliability analysis. The presenter discusses the 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 from 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 hand in after every session. The sessions are executed in groups 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 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 and defended against 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 31<sup>th</sup> of May 2019. Depending on the quality, the participant can gain up to 2 course points extra (affecting grade).
  - **Identifying calculation errors** in the course material and correct solution will add 0.5 course points for each detected error and solution to the total course points.
  - **Maximal 2 course points** can be added to the overall course points from the two aforementioned tasks.

## Course material

The course is based on the book:

1. C. J. Wallnerström, P. 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 recommended books are presented on page 36 in book 1. Other relevant course books are:

2. Roy Billinton and Ron Allan, "Reliability Evaluation of Power Systems", 2nd edition.
3. Rausand, M., & Høyland, A. (2004). *System reliability theory: models, statistical methods, and applications* (Vol. 396). John Wiley & Sons.

(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 two parts:

- **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 [sanjadz@kth.se](mailto:sanjadz@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 according on the 7 step scale of the ECTS system (e.g. A-E, pass; Fx not passed but having a possibility to upgrade without taking the re-exam; F failed).

Maximum examination points for each part are:

- 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)

## 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 **9<sup>th</sup> of April 2019**.
- The reports of the laboratories have to be submitted latest on **17<sup>th</sup> of April 2019** for laboratory 1 and latest on **14<sup>th</sup> of May 2019** for laboratory 2.
- The home assignment must be submitted until **17<sup>th</sup> of May 2019**.
- The project reports must be submitted by **17<sup>th</sup> of May 2019**.
- The final version of the project report must be submitted by **31<sup>th</sup> of May 2019**.

## 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 the deadline can only achieve a pass with 0 examination points. If a laboratory or project report is handed in after the deadline, it can add -0.5 examination points to the overall student examination score. Moreover, reports handed in after the **31<sup>th</sup> of May** will not be considered anymore in the given year.

## Contact information

KTH Royal Institute of Technology  
Electromagnetic Engineering  
Teknikringen 31  
100 44 Stockholm

### *Examiner and lecturer*

Patrik Hilber, telephone 08-790 7772, e-post [patrik.hilber@ee.kth.se](mailto:patrik.hilber@ee.kth.se)

### *Course responsible*

Sanja Duvnjak Žarković, [sanjadz@kth.se](mailto:sanjadz@kth.se)

### *Course assistants*

Jan Henning Jürgensen, [jhjur@kth.se](mailto:jhjur@kth.se)

Kateryna Morozovska, [kmor@kth.se](mailto:kmor@kth.se)

Ebrahim Shayesteh, [ebrahim.shayesteh@ee.kth.se](mailto:ebrahim.shayesteh@ee.kth.se)

Per Westerlund, [perw@kth.se](mailto:perw@kth.se)

## 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 (F), 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), Kateryna Morozovska (KM), Per Westerlund (PW), Jan Henning Jürgensen (JHJ), 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> . This year all lectures and exercises are in Room Ivar Herlitz, Teknikringen (TR) 33, KTH Main Campus.

### Course part 1:

<i>Code</i>	<i>Content</i>	<i>Lecturer</i>	<i>Room</i>	<i>Time</i>	<i>Day</i>
F1a	Course introduction	JHJ, SDZ, All	TR33,Ivar Herlitz Room	10-11	Tue 26 March
F1b	Introduction to the field of reliability analysis	PH	TR33,Ivar Herlitz Room	11-12	Tue 26 March
F2	Introduction to Markov models	PW	TR33,Ivar Herlitz Room	13-15	Tue 26 March
F3	Risk and vulnerability analysis	ES	TR33,Ivar Herlitz Room	15-17	Tue 26 March
F4	Failure models	JHJ	TR33,Ivar Herlitz Room	8-10	Wed 27 March
F5	Markov models	ES	TR33,Ivar Herlitz Room	10-12	Wed 27 March
F6	Methods for power system analysis	ES	TR31, Gustaf Dahlander Room	13-15	Wed 27 March
Ö1	Exercise	SDZ, All	TR33,Ivar Herlitz Room	15-17	Wed 27 March
F7	Methods for analysis of the power grid and stations	ES	TR33,Ivar Herlitz Room	8-11	Thu 28 March
Ö2, Lab	Defining and preparing the project and the laboratory	SDZ, All	TR33,Ivar Herlitz Room	11-12	Thu 28 March
F8	Approximative methods for system analysis	PH	Video lecture		Thu 28 March

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

**Course part 2:**

<b>Code</b>	<b>Content</b>	<b>Lecturer</b>	<b>Room</b>	<b>Time</b>	<b>Day</b>
TEN1	Exam	All	TR33,Ivar Herlitz Room	10-12	Tue 9 April
F9	Guest lecture	SDZ, All	TR33,Ivar Herlitz Room	13-15	Tue 9 April
F10	Economic analysis, introduction	JHJ	TR33,Ivar Herlitz Room	15-17	Tue 9 April
F11	Presentation of problem descriptions	All, students	TR33,Ivar Herlitz Room	17-18	Tue 9 April
Lab1	<b>Laboratory part 1:</b> Reliability analysis of the power grid - introduction and NEPLAN exercise	SDZ	TR33, Computer room Frances Hugle	13-17	Wed 10 April
F12	Asset Management	KM	Video lecture		Wed 10 April
F13	Methods for reliability importance	PH	Video lecture		Wed 10 April

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

**Course part 3:**

<b>Code</b>	<b>Content</b>	<b>Lecturer</b>	<b>Room</b>	<b>Time</b>	<b>Day</b>
F14	Cost- and LCC-analysis	JHJ	TR33,Ivar Herlitz Room	10-12	Tue 7 May
Lab2	Laboratory part 2: <i>LCC-analysis for the power grid with an example of an actual case study within RCAM</i>	JHJ	TR33,Ivar Herlitz Room	13-17	Tue 7 May
Dinner	Course dinner	Optional	To be decided	17-20	Tue 7 May
F15	Lifetime analysis	PW	TR33,Ivar Herlitz Room	8-10	Wed 8 May
F16	Introduction to Monte Carlo simulations	ES	TR33,Ivar Herlitz Room	10-12	Wed 8 May
F17	Methods for reliability centred maintenance	PH, ES	TR33,Ivar Herlitz Room	13-15	Wed 8 May
Ö, P	Theory recap & Project Work	SDZ, All	TR33,Ivar Herlitz Room	15-17	Wed 8 May
<b>Re-exam</b>	<b>Re-exam</b> – second opportunity to successfully pass the written examination.	<b>SDZ, All</b>	<b>TR33,Ivar Herlitz Room</b>	10-12	Thu 9 May

**Home assignment:** Due on 17<sup>th</sup> of May 2019

<i>Code</i>	<i>Content</i>	<i>Lecturer</i>	<i>Room</i>	<i>Time</i>	<i>Day</i>
<b>TEN2</b>	<b>Home assignment</b>	<b>All</b>	<b>n/a</b>	<b>n/a</b>	<b>Fri 17 May</b>

**Own work before the last seminar:** finishing the project report and preparing for the oral presentation and reviewing another students report

**Seminar:**

<i>Code</i>	<i>Content</i>	<i>Lecturer</i>	<i>Room</i>	<i>Time</i>	<i>Day</i>
<b>SEM</b>	<b>Seminar:</b> oral presentation with questions from the reviewers and others	<b>All</b>	<b>TR33,Ivar Herlitz Room</b>	<b>10-16</b>	<b>Wed 22 May</b>