**Title:**
TET4115 Power System Analysis

**Credit value:**
7.5 ECTS

**Mandatory/Optional:**
Mandatory

**Semester:**
3

**Lecturer/s:**
Associate Professor Vijay Venu Vadlamudi/ Prof. Kjetil Uhlen

**University:**
Norwegian University of Science and Technology (NTNU)

**Department:**
Department of Electric Power Engineering

**Rationale:**
A rigorous analysis of power systems is essential to the understanding of their complexity. This analysis forms a strong foundation for the effective and reliable planning and operation of power systems. No matter what the changing facets of power systems are – deregulation, smart grid-oriented paradigms, the study and practice of electric power engineering requires exposure to sound analytical approaches from a systems perspective. This course caters to such requirements, and subsequently paves the way for computer-aided power system analysis.

**Objectives:**
The main objective of the course is to gain a good understanding on performing power system analysis in normal operation and under symmetrical and unsymmetrical faults, including basic principles for protection against such faults. Additionally, the students will learn basic principles for the formulation and application of optimal power flow. Further, the learning outcomes are complemented with the usage of simulation tools.

**Skills:** (according to the list of skills provided)

<table>
<thead>
<tr>
<th>Subject skills</th>
<th>REM Master Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>L3.1. To establish and use power system models based on nodal admittance and impedance matrices for the analysis of large power networks.</td>
<td>X X</td>
</tr>
<tr>
<td>L3.2. To model generators, transformers, lines and cables in the positive, negative and zero sequences as a basis for analysis of symmetrical and unsymmetrical faults.</td>
<td>X X X</td>
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<tr>
<td>L3.3. To define, establish and solve equations for regular power flow, approximated (DC) power flow, and optimal power flow.</td>
<td>X X</td>
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<td>L3.4. To be able to use simulation tools to perform load flow and short circuit studies.</td>
<td>X X</td>
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<tr>
<td>L3.5. To gain understanding of the basic principles of power system protection (introductory level).</td>
<td>X X X</td>
</tr>
<tr>
<td>L3.6. To observe the phenomena of earth fault current in distribution networks in laboratory, and apply the theory on fault analysis to validate the observations. (Also, increase the ability to use</td>
<td>X</td>
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</tbody>
</table>
To acquire skills in group work and in working independently, acquire critical thinking through analysis and synthesis, systematically organize information, and create effective assignment, lab and project reports.

**Teaching and learning methods:**
The course methodology includes various techniques such as individualised and group learning methods, combining both throughout the whole learning process. Lectures, tutorials, project and lab sessions are used:
1. Lecture format with oral and audiovisual presentations. Also includes guest lectures.
2. Compulsory exercises, compulsory lab work, and compulsory project work.
3. Individual monitoring of the learning process is done through mentoring/guidance by the student assistants, research assistant, and the lecturers.

**Allocation of student time:**

<table>
<thead>
<tr>
<th>Attendance (classroom, lab,…)</th>
<th>Non attendance (lecture preparation, self study…)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lectures</td>
<td>56 hours</td>
</tr>
<tr>
<td>Tutorials</td>
<td>20 hours</td>
</tr>
<tr>
<td>Project</td>
<td>4 hours</td>
</tr>
<tr>
<td>Laboratory</td>
<td>4 hours</td>
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</tbody>
</table>

**Assessment:**
*Procedures for assessment of the course:*
1. There will be a portfolio assessment of in-semester exam, project work and take-home exam together constituting 100% weightage.
2. The student has to successfully complete mandatory exercises, and lab work.

Note: The Assessment rules might vary from year to year. The students will be notified at the beginning of the semester of such changes.

**Assessment Matrix:**

<table>
<thead>
<tr>
<th>Subject skills</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exam</td>
</tr>
<tr>
<td>L3.1.</td>
<td>100%</td>
</tr>
<tr>
<td>L3.2.</td>
<td>100%</td>
</tr>
<tr>
<td>L3.3.</td>
<td>100%</td>
</tr>
<tr>
<td>L3.4.</td>
<td>100%</td>
</tr>
<tr>
<td>L3.5.</td>
<td>100%</td>
</tr>
<tr>
<td>L3.6.</td>
<td></td>
</tr>
<tr>
<td>L3.7.</td>
<td></td>
</tr>
</tbody>
</table>
**Programme:** Distribution (2 h theory per lesson)

| Lesson 1 | Basic concepts in power system analysis, Per-unit systems |
| Lesson 2 | (Contd.) Basic concepts in power system analysis, Per-unit systems |
| Lesson 3 | System topology and network equations – Bus admittance and impedance forms |
| Lesson 4 | (Contd.) System topology and network equations – Bus admittance and impedance forms |
| Lesson 5 | Review of Transmission Systems - Voltage drop, compensation |
| Lesson 6 | Introductory Matlab Session |
| Lesson 7 | Short Circuit Studies – Symmetrical Faults  
Introduction to Faults, use of Thevenin’s theorem, use of bus impedance matrix |
| Lesson 8 | (Contd.) Short Circuit Studies – Symmetrical component theory  
Fortescue’s Theorem, sequence diagrams for lines, loads, generators and transformers |
| Lesson 9 | (Contd.) Short Circuit Studies – Symmetrical component theory  
Fortescue’s Theorem, sequence diagrams for lines, loads, generators and transformers |
| Lesson 10 | (Contd.) Short Circuit Studies – Unsymmetrical Faults  
Procedure to obtain positive, negative and zero sequence networks for power systems. |
| Lesson 11 | (Contd.) Short Circuit Studies – Unsymmetrical Faults  
Generic matrix expressions |
| Lesson 12 | (Contd.) Short Circuit Studies – Unsymmetrical Faults  
Terminal conditions for SLG, LL and LLG faults |
| Lesson 13 | (Contd.) Short Circuit Studies – Unsymmetrical Faults  
Algorithmic approach using ZBus to conduct unsymmetrical fault Studies for SLG, LL, and LLG faults. |
| Lesson 14 | Conclusion: Short Circuit Studies – Unsymmetrical Faults  
Peterson coil and grounding. |
| Lesson 15 | Conclusion: Short Circuit Studies – Unsymmetrical Faults  
Peterson coil and grounding. |
| Lesson 16 | Power Flow Studies – AC  
Classification of buses, formulation of the power flow problem |
| Lesson 17 | (Contd.) Power Flow Studies – AC  
Solution of the power flow problem using Newton Raphson method |
| Lesson 18 | (Contd.) Power Flow Studies – AC  
Example on the solution of the power flow problem using Newton Raphson method |
| Lesson 19 | (Contd.) Power Flow Studies – DC  
Approximations and comparisons |
| Lesson 20 | Optimal Power Flow (OPF) Studies  
Economic dispatch, introduction to optimization |
| Lesson 21 | Optimal Power Flow (OPF) Studies  
Formulation of the OPF problem |
| Lesson 22 | Optimal Power Flow (OPF) Studies  
Solution of the power flow problem using Steepest Gradient method |
| Lesson 23 | Conclusion: Power Flow and Optimal Power Flow Studies  
Case Studies |
| Lesson 24 | Conclusion: Power Flow and Optimal Power Flow Studies  
Case Studies |
| Lesson 25 | Power System Protection Studies – Overview |
### Lesson 26
Guest Lectures on State-of-art Topics in Power Systems

### Lesson 27
Miscellaneous

### Lesson 28
Course Summary

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**Resources:**

- Classroom, Blackboard, laptop, projector, audio, computer room, laboratory.
- All the material necessary to follow the course is facilitated by the course instructors during the course, through ‘eLS’ (e-Learning System) platform (known as ‘Blackboard’).

**Bibliography:**

**Textbooks:**


**Additional Recommended Reading:**


**Further comments:**

**Deviations:** Since the teaching and learning processes are adaptive, there may arise minor deviations in the course schedule and content.