REM master basic syllabus

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)*

Subject skills	REM Master Skills						
	L2.1	L2.2	L2.3	L2.4	L2.5	L2.6	L2.7
L3.1. To establish and use power system models based on nodal admittance and impedance matrices for the analysis of large power networks.	X		X				
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.	X	X	X				
L3.3. To define, establish and solve equations for regular power flow, approximated (DC) power flow, and optimal power flow.	X		X				
L3.4. To be able to use simulation tools to perform load flow and short circuit studies.	X		X				
L3.5. To gain understanding of the basic principles of power system protection (introductory level).	X	X	X				
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			X				

instruments and equipment in the laboratory.)							
L3.7. 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.						X	X

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:

	Attendance (classroom, lab,…)	**Non attendance (lecture preparation, self study…)**
Lectures	56 hours	84 hours in total of self-preparation; this also includes group project work.
Tutorials	20 hours	
Project	4 hours	
Laboratory	4 hours	

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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:

Subject skills	**Assessment method**					
	Exam	**Presentation**	**Homework**	**Report**	**Lab Participation**	
L3.1.	100%					
L3.2.	100%					
L3.3.	100%					
L3.4.	100%					
L3.5.	100%					
L3.6.					100%	
L3.7.				100%		

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

<u>Resources:</u>
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).

<u>Bibliography:</u>
Textbooks:
[1] H. Saadat, "Power System Analysis", PSA Publishing, Third Edition, 2010. ISBN-10: 0984543805
[2] J. D. Glover, T. Overbye, M. S. Sarma, "Power System Analysis and Design", Cengage Learning (CL) Engineering, Sixth Edition, 2016. ISBN-10: 1305632133

Additional Recommended Reading:
[3] J. Grainger and W. Stevenson Jr., "Power System Analysis", McGraw-Hill International Edition, 1994. ISBN-10: 0070612935

<u>Further comments:</u>

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