Course Outline

Academic Year	AY2019/2020		**Semester**	2
Course Coordinator	Wang Peng			
Course Code	EE4533			
Course Title	Power Apparatus and System Protection			
Pre-requisites	Before AY2021-22 Sem2:	EE3010 Electrical Devices & Machines and EE3015 Power Systems & Conversion		
	AY2021-22 Sem2 and onwards:	EE3010 Electrical Devices & Machines and EE3015 Power Systems & Conversion or EE2005 Electrical Devices & Machines and EE3015 Power Systems & Conversion		
No of AUs	3			
Contact Hours	Lectures: 26 hours; Tutorial: 12 hours			
Proposal Date	5 March 2020 (REF#ACC-CN-2020/06_ITN-02)			

Course Aims

In this course, you will learn about power system apparatus and their protection. In particular, you will learn about the various high voltage power apparatus, their maintenance and condition monitoring, and transients in power system as well as fault analysis and protection of the power apparatus. These knowledge would support you in your work as an engineer under the direction of an authorized personnel to test HV apparatus and carry out operation, maintenance work and protection design for HV equipment.

Intended Learning Outcomes (ILO)

On completion of this course, you would be able to:

1. Describe and explain substation bus bar arrangement and the operation and application of switchgear.
2. Identify system and equipment earthing.
3. Describe and analyze electrical transients in power systems.
4. Describe over voltages and insulation coordination
5. Describe HV testing of electrical apparatus.
6. Apply condition-based monitoring techniques to increase the reliability of the apparatus/system.
7. Perform common fault analysis for both (a) balanced and (b) unbalanced power systems.
8. Explain how over-current and differential relays are used to protect power apparatus such as transformers, transmission lines, and generators.

Course Content

Power Apparatus and Transients. High Voltage Testing and Maintenance. Fault Analysis. Protection of Distribution Systems. Protection of Power Apparatus.

Course Outline

S/N	Topic	Lecture Hours	Tutorial Hours
1	Substation bus bar arrangement and types of Circuit Breakers	2	1
2	System and equipment earthing	2	1
3	Electrical transients	2	1
4	Over voltages and insulation coordination	2	1
5	HV testing of electrical apparatus	2	1
6	Fault locating methods and condition-based monitoring techniques	2	1
7	Review of power system concepts	2	1
8	Sequence components	2	1
9	Sequence networks and fault analysis	4	1
11	Overcurrent protection	3	2
12	Differential protection	3	1
	Total hours	**26**	**12**

Assessment (includes both continuous and summative assessment)

Component	**Course LO Tested**	**Related Programme LO or Graduate Attributes**	**Weighting**	**Team/ Individual**	**Assessment rubrics**
1. Final Examination	1-8	EAB SLO* a, b, c	60%	Individual	
2. Continuous Assessment 1 (CA1): Quiz 1	1-3	EAB SLO* a, b, c	10%	Individual	
3. CA2: Mini Research Project	1-6	EAB SLO* a, b, c, d, j, i, e	20%	Individual	
4. CA3: Quiz 2	7-8	EAB SLO* a, b, c	10%	Individual	
Total			100%		

* EAB SLO stands for the Engineering Accreditation Board Student Learning Outcomes. The list is below:

a) **Engineering knowledge:** Apply the knowledge of mathematics, natural science, engineering fundamentals, and an engineering specialisation to the solution of complex engineering problems.

b) **Problem Analysis:** Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

c) **Design/development of Solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.

d) **Investigation:** Conduct investigations of complex problems using research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions

e) **Modern Tool Usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.

f) **The engineer and Society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

g) **Environment and Sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for the sustainable development.

h) **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

i) **Individual and Team Work:** Function effectively as an individual, and as a member or leader in diverse teams and in multidisciplinary settings.

j) **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

k) **Project Management and Finance:** Demonstrate knowledge and understanding of the engineering and management principles and economic decision-making, and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

l) **Life-long Learning:** Recognise the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Mapping of Course SLOs to EAB Graduate Attributes

Course Student Learning Outcomes	**Cat**	**EAB's 12 Graduate Attributes***											
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)
EE4533 Power Apparatus and System Protection	PE	●	◐	●	◐	◐				◐	◐		

1. Understand substation bus bar arrangement and the operation and application of switchgear.	EAB SLO a
2. Understand equipment and system earthing.	EAB SLO a, b
3. Understand and analyze electrical transients in power systems.	EAB SLO a, b

4. Understand over voltages and insulation coordination	EAB SLO a
5. Understand HV testing of electrical apparatus.	EAB SLO a
6. Apply condition-based monitoring techniques to increase the reliability of the apparatus/system.	EAB SLO a, d
7. Perform common fault analysis for both (a) balanced and (b) unbalanced power systems.	EAB SLO a, b
8. Explain how over-current and differential relays are used to protect power apparatus such as transformers, transmission lines, and generators.	EAB SLO a, b, c

Legend:
- ● Fully consistent (contributes to more than 75% of Student Learning Outcomes)
- ◐ Partially consistent (contributes to about 50% of Student Learning Outcomes)
- ○ Weakly consistent (contributes to about 25% of Student Learning Outcomes)
- Blank Not related to Student Learning Outcomes

Formative feedback

Quiz scores;
Scores and comments for research done on an assigned topic;
Examination results;
Markers' report on overall examination performance.

Learning and Teaching approach

Approach	How does this approach support students in achieving the learning outcomes?
LECTURE	Weekly lectures.
TUTORIAL	12 Tutorial sessions to help students achieve the learning outcomes

Reading and References

TEXTBOOKS

1. Farouk A M.Rizk and Giao N. Trinh, High Voltage Engineering, CRC Press, 2014. XX(1317900.1)
2. Hugh M Ryan, High Voltage Engineering Testing, IET, 2013. XX(1871098.1)
3. Blackburn J Lewis, Protective Relaying: Principles and Applications, 4th Edition, CRC Press, 2014. (TK2861.B628 2014)

REFERENCES

1. Naidu M S and Kamaraju V, High Voltage Engineering, 5th Edition, McGraw-Hill, 2013. (TK3001.N155

2013)
2. Ram Badri and Vishwakarma D N, Power System Protection and Switchgear, 2nd Edition, Tata McGraw-Hill, 2011. (TK2861.R165 2011)
3. Weedy Birron Mathew and Cory Brian John, Electric Power Systems, 5th Edition, John Wiley, 2012. (TK1001.W394 2012)
4. Anderson Paul M, Power System Protection, McGraw-Hill, IEEE Press, 1999. (TK1010.A548)

Course Policies and Student Responsibilities

Refer to the links for:

Course policies:
http://www.ntu.edu.sg/Students/Undergraduate/AcademicServices/Pages/AcademicUnitSystem(AUS).aspx

CA guidelines:
http://www.eee.ntu.edu.sg/Programmes/CurrentStudents/undergraduate/undergraduatefull-time/Pages/CourseRegistration.aspx

Instructions to Examination Candidates:
http://www.ntu.edu.sg/Students/Undergraduate/AcademicServices/Examination/pages/instructionstoexamcand.aspx

Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

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Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	Substation bus arrangement	1	No tutorial this week
2	Circuit Breakers, Arc interruption, types of CB	1	Tutorial 1 – bus bar arrangement
3	Equipment and system earthing	2	Tutorial 2 – CB
4	Switching transients and over-voltages	3	Tutorial 3 – Earthing
5	HV testing	4	Tutorial 4 – Electrical transients, Quiz #1 in LT
6	Fault location and condition monitoring techniques	5	Tutorial 5– HV testing
7	Review of power system concepts	6	Tutorial 6– Condition monitoring, Research project
Recess			
8	Sequence components	6	Tutorial 7: Three Phase Power Systems
9	Sequence networks and fault analysis	6	Tutorial 8: Sequence Components and Sequence Networks
10	Sequence networks and fault analysis	6	Tutorial 9: Fault Currents and Voltages
11	Overcurrent protection	7	Tutorial 10: Fault Analysis
12	Differential protection	7	Tutorial 11: Protection Zone and Overcurrent Protection, Quiz #2 in LT
13	Protection of power apparatus	8	Tutorial 12: Differential Protection