COURSE OUTLINE

Academic Year	AY2019-2020		**Semester**	2
Course Coordinator	Dr. Foo Yi Shyh Eddy			
Course Code	EE4534			
Course Title	MODERN DISTRIBUTION SYSTEMS WITH RENEWABLE RESOURCES			
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, Tutorials: 12 hours			
Proposal Date	5 March 2020 (REF#ACC-CN-2020/06_ITN-02)			

Course Aims

This course deals with the operation of modern electric power distribution systems, which are increasingly being connected with renewable energy sources. It discusses many overriding factors, particularly system efficiency and cost-effectiveness. In addition, power quality issues are addressed with specific focus on the impacts on modern electronic appliances and renewable generations. Greater emphasis is also given to the two widely tapped clean energy sources of solar and wind. The course aims to equip students with the fundamentals of renewable energy sources through comprehensive coverage of energy conversion processes to their applications. The topics taught complement the understanding of power distribution systems with integration of renewable energy sources and their impacts on each other. The knowledge gained will prepare students well when they embark on careers involving electrical power distribution or in consulting companies. The course is also an excellent starting point for pursuing graduate studies in renewable energy technologies and power quality.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, you should be able to:

1) Apply the relevant technical concepts in the design and operation of distribution systems.
2) Identify and describe the operational aspect of renewable energy generations, and the various issues pertaining to their interconnections to the distribution grids.
3) Identify and explain the options available for ensuring the continuity of electricity supply and a power quality that is commensurate with the needs of electrical equipment.
4) Describe economical aspects of electricity generation and usage besides the technical issues.

Course Content

Operation of distribution systems. Power quality. Solar power systems. Wind power systems.

Course Outline

S/N	Topic	Lecture Hours	Tutorial Hours

1	Operation of Distribution Systems Distribution network configurations. Planning criteria and network design. Load management. Energy losses and power factor control. Industrial energy conservation. Electricity tariff. Maximum demand management.	6	3
2	Power Quality Voltage sags, swells and interruptions. Voltage sag mitigation techniques. Voltage fluctuation and imbalance. Harmonic distortions. Harmonic filter design. Power quality solutions.	8	3
3	Solar Power Systems Introduction to renewable resources. Solar radiation. Insolation. Solar collectors. Photovoltaics. Cell characteristics. Series and parallel connection of PV cells. Maximum Power Point Tracking. Grid connection.	6	3
4	Wind Power Systems Energy and power in wind. Induction and synchronous generators. General characteristics of wind resources. Power converter control. Speed control for maximum power.	6	3
	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. CA1 – Quiz #1	2	EAB SLO* a, c	10%	Individual	
2. CA2 – Quiz #2	1,3	EAB SLO* a, c	10%	Individual	
3. CA3 – Homework Assignment #1	2	EAB SLO* a, b, c	10%	Individual	
4. CA4 – Homework Assignment #2	1,3,4	EAB SLO* a, b, c	10%	Individual	
5. Final Examination	1,2,3,4	EAB SLO* a, c	60%	Individual	
Total			**100%**		
* Please refer to Appendix 2 on the EAB accreditation SLOs					

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)
EE4534 Modern Distribution System with Renewable Resources	Major-PE	●	◐	●									

1.	Apply the relevant technical concepts in the design and operation of distribution systems.	EAB SLO* a, b, c
2.	Identify and describe the operational aspect of renewable energy generations, and the various issues pertaining to their interconnections to the distribution grids.	EAB SLO* a, b, c
3.	Identify and explain the options available for ensuring the continuity of electricity supply and a power quality that is commensurate with the needs of electrical equipment.	EAB SLO* a, b, c
4.	Describe economical aspects of electricity generation and usage besides technical issues.	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

These are the forms of feedback that you can expect in the course:

Your exercises in tutorial classes;
Examination results;
Markers' report on overall examination performance;
Quizzes scores and answers / solutions / explanations provided in tutorial/lecture classes;
Assignment scores uploaded on course site.

Learning and Teaching approach

Approach	How does this approach support students in achieving the learning outcomes?
LECTURE	Lectures and lecture materials cover all topics
TUTORIAL	Classroom discussions on tutorial questions and related topics

Reading and References

TEXTBOOKS

1. Pabla A S, Electric Power Distribution, 6th Edition, McGraw-Hill, 2011. (TK3001.P112e 2011)
2. Masters Gilbert M, Renewable and Efficient Electric Power Systems, 2nd Edition, John Wiley, 2013. (TK1005.M423 2013)

REFERENCES

1. Dugan Roger C, McGranaghan M F, Santoso S and Beaty H Wayne, Electrical Power Systems Quality, 3rd Edition, McGraw-Hill, 2012. (TK1010.D866 2012)
2. Boyle Godfrey, Renewable Energy: Power for A Sustainable Future, 3rd Edition, Oxford University Press, 2012. (TJ808.R411re 2012)

Course Policies and Student Responsibilities

General:
You are expected to complete all tutorial questions and take-home assignment by due dates. You are expected to take all quizzes. You are expected to take responsibility to follow up with course notes, assignments and course related announcements. You are expected to actively participate in class discussions.

Continuous assessments:
You are required to attend all continuous assessments.

Absenteeism:
Continuous assessments make up a significant portion of your course grade. Absence from continuous assessments without officially approved leave will result in no marks and affect your overall course grade.

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

Instructor	Office Location	Phone	Email
Dr. Foo Yi Shyh Eddy	S1-B1C-89	6790 4519	eddyfoo@ntu.edu.sg
A/P Josep Pou	S2-B2A-06	6790 4503	j.pou@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	The Wind Energy Resource: Introduction to renewables, wind resource, power in the wind, impact of height	2	2 lectures
2	Wind Turbines: Types of wind turbines, components of wind turbines, efficiency of wind turbines, components of wind turbines	2	2 lectures + 1 tutorial
3	Grid Integration of Wind Turbine Generators: Types of wind turbine generators, doubly-fed induction	2	2 lectures + 1 tutorial

	generators, permanent magnet synchronous generators.		
4	The Solar Resource: Solar spectrum, sun paths, sun path diagrams, solar insolation	2	2 lectures + 1 tutorial + Homework Assignment #1
5	Solar Photovoltaic Technology: Photovoltaic semiconductor, solar cells, modules and arrays, solar PV I-V characteristics, effects of insolation and temperature	2	2 lectures + 1 tutorial + Quiz #1
6	Grid Integration of Solar Photovoltaic System: Integration techniques and issues, solar PV interaction with loads	2	2 lectures + 1 tutorial
7	Background,Distribution of power, Distribution System Planning Load factor, Load shape changes, Load management, Energy management of electrical equipment Energy losses in power system, losses in transformers, cables and lines	1	2 lectures + 1 tutorial
Recess	Recess Week		
8	Power flow and power factor, Power factor improvement, Most economic power factor, Optimal placement of capacitor, Synchronous condensers Pricing of Electricity, Electricity Tariff Structure, Typical electric charges, Singapore Electricity Tariff, Rate design for DSM Energy Management, Maximum Demand Management, Duty cycling, Load shedding, Optimal scheduling	1,4	2 lectures + 1 tutorial
9	Introduction of Power Quality, Electromagnetic phenomena, Impact of poor power quality, Tackling power quality problem, Power quality in Singapore Voltage variations, Causes of voltage variations, Short circuit capacity, Effect of reactive loads, Voltage sags due to motor-starting	1,3	2 lectures + 1 tutorial
10	Fault induced voltage sags, Voltage regulation, Voltage fluctuation / flicker	1,3	2 lectures + 1 tutorial + Homework Assignment #2

	Introduction to harmonics, Characterization of harmonic distortions, Source of harmonics, Typical harmonic characteristics		
11	Symmetrical components & triplens, System response to harmonics Parallel resonance, Series resonance	1,3	2 lectures + 1 tutorial + Quiz #2
12	Harmonic mitigation techniques, Design of harmonic tuned filters	1,3	2 lectures + 1 tutorial
13	Harmonic limits, Summary Review and wrap up of lecture/CA/Assignment materials. Discuss all materials.	1,3	2 lectures + 1 tutorial

Appendix 2: The EAB (Engineering Accreditation Board) Accreditation SLOs (Student Learning Outcomes)

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.