UNIVERSITY OF WATERLOO

Department of Electrical & Computer Engineering

ECE6601PD: Power System Components and Modeling
Course Outline
Fall 2024

Instructor:
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Online Lectures: TBA, with a 20 min break midway through. Due to travel commitments, some lectures might have to be rescheduled in October and November.

Objectives:
- Learn in detail the basic structure, functional characteristics and protection schemes of the main components that make up a powers system, in particular generators, transformers, transmission lines, cables, loads, HVDC, Flexible AC Transmission System (FACTS) controllers, and Renewable Energy Sources (RES).
- Understand the modeling and simulation of these components for detailed electromagnetic transients analyses, as well as phasor models for power flow and stability studies.

Content:

Weeks	Topics	Sub-Topics

4	Generation Plant	• Power system overview.
		• Supply technologies.
		• Generation plant components.
		• Synchronous machine.
		• Dynamic models of generators for stability analysis:
		  o Subtransient model.
		  o Transient model.
		  o Basic control models
		• Steady state model.
		• Sequence (symmetrical component) models.
		• Generator-system dynamic behavior.
		• Overview of protections.

2	Transformers	• Single phase:
		  o Detailed model.
		  o Phasor models.
		• Three phase:
		  o Connections.
		  o Models.
		• Sequence (symmetrical component) models.
		• Special Transformers:
		  o Three-winding transformers.
		  o Zig-zag transformers.
		  o Autotransformers.
		• Saturation and inrush currents.
		• Controls:
		  o Load tap changers (LTCs).
		  o Phase shifters.
		• Overview of protections.

2	Transmission Lines and Cables	• Transmission Lines:
		  o Single phase:
		  ▪ Distributed parameter model.
		  ▪ Phasor lumped model.
		  o Three phase:
		  ▪ Distributed parameter model.
		  ▪ Reduced models.
		  o Sequence (symmetrical components) models.
		• Underground cables.
		• Overview of protections.

2	Loads	• RLC loads.
		• Induction motors:
		  o Detailed model.
		  o Phasor models.
		• Aggregate load models:
		  o Impedance models.
		  o Power models.
		  o Induction motor power models.
		• Sequence (symmetrical components) models.
		• Overview of protections.

1	HVDC	• Basic structure and operation. • Commutation. • Harmonics. • DC links. • Controls. • Fundamental frequency, reduced model. • Steady state model. • Faults and protections

1	FACTS	• Shunt, series and phase-shifting compensation.
		• Thyristor Control:
		  o Thyristor Controlled Reactor–Fixed capacitor (TCR-FC).
		  o Static Var Compensator (SVC).
		  o Thyristor Controlled Series Capacitor (TCSC).
		  o Thyristor Controlled Voltage Regulator (TCVR) and Thyristor Controlled Phase Angle Regulator (TCPAR).
		• Voltage-Sourced Converters (VSC):
		  o VSC operation.
		  o Shunt Static Synchronous Compensator (STATCOM).
		  o Series Static Synchronous Compensator (SSSC).
		  o Unified Power Flow Controller (UPFC).
		  o Interline Power Flow Controller (IPFC).
		  o Convertible Static Compensator (CSC).
		  o Hybrid Power Flow Controller (HPFC)
		  o HVDC light.
		• D-FACTS:
		  o DSTATCOM.
		  o DSMES.
		• Examples.

	RES	• Solar PV Generation (SPVG). • Wind-turbine Generation (WG). • Battery Energy Storage System (BESS). • Examples.

References:

1. J. Arrillaga and N. R. Watson, *Computer Modeling of Electrical Power Systems*, 2nd edition, John Willey, 2001, ISBN 0-471-87249-0. (Simplified models of generators and HVDC.)
2. N. G. Hingorani and L. Gyugyi, *Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems*, IEEE Press, 2000. (FACTS.)

3. J. Arrillaga, *High Voltage Direct Current Transmission*, 2nd edition, IET, 1998. (HVDC.)
4. *Transmission and Distribution Reference Book*, 5th edition, ABB, 1997. (Transformers and some protections.)
5. *Electromagnetic Transients Program Reference Manual (EMTP Theory Book)*, BPA, 1986. (Generators and transmission lines, and some transformer and load models.)
6. P. Kundur, *Power System Stability and Control*, McGraw-Hill, 1994, ISBN 0-07-035958-X. (Generator models.)
7. P. Anderson, *Power System Protection,* IEEE, 1998, ISBN 9780470545591. (Protections.)
8. A. Gómez-Expósito, A. J. Conejo and C. A. Cañizares, Editors, *Electric Energy Systems: Analysis and Operation*, 2nd edition, CRC Press, June 2018, ISBN 9781315192246. (Simplified models of all elements.)
9. C. A. Gross, *Power System Analysis*, 2nd edition, John Wiley, 1986. (Simplified models of lines and transformers.)
10. J. Yin et al., *Unified Power Flow Controller Technology and Application*, Academic Press, Elsevier, 2017. (UPFC examples.)
11. Journal papers, technical reports and websites (available on-line).
12. Course notes available at course website.

Requisites: Basic knowledge of power systems and modeling is required. Good knowledge of MATLAB is required.

MT Assgn.: Based on problems presented and discussed during lectures regarding the various topics discussed in class. Some problems will require the use of MATLAB.

Projects:

1. Detailed and phasor modeling and simulation of a generator using MATLAB.
2. Detailed and phasor modeling and simulation of a transmission line and load using MATLAB.

Marking:

Projects (2)	→	40 % (TBA)
Midterm Assign.	→	10 % (TBA)
Final Exam	→	50 % (TBA)

Important Notes:

- Academic Integrity: Please read www.uwaterloo.ca/academicintegrity/
- Grievance: Please read Policy 70, Student Petitions and Grievances, Section 4, at www.adm.uwaterloo.ca/infosec/Policies/policy70.htm.
- Discipline: Please read Policy 71, Student Discipline, at www.adm.uwaterloo.ca/infosec/Policies/policy71.htm, and Guidelines for the Assessment of Penalties at www.adm.uwaterloo.ca/infosec/guidelines/penaltyguidelines.htm.
- Appeals: A student who believes he/she has a ground for an appeal should refer to Policy 72 (Student Appeals) at www.adm.uwaterloo.ca/infosec/Policies/policy72.htm.