Winter 2021

Department of Electrical and Computer Engineering
University of Waterloo

ECE 464 High Voltage Engineering and Power System Protection 3C 1T 1L 0.5

Course Description

The course provides the fundamental concepts of generation and measurements of high voltage ac, dc, and impulses. Briefly introduces the students to basic conduction and breakdown mechanisms of insulating materials. The scope of this course also includes understanding the basic protection system, studying the principles for protecting different elements and studying different technologies used in protection. Exposure to several state-of-the-art high voltage testing techniques of power components will ensure that students have knowledge of the industrial solutions to the management of the problems associated with overvoltage and the protection mechanisms used.

For a detailed description: See pages 2, 3, and 4.

Reference Materials:

High Voltage Engineering – Fundamentals, 2nd edition, E. Kuffel, W. S. Zaengl and J. Kuffel, Newnes, 2000. An electronic version is available in UW Library, and on the course web site on LEARN, Any additional reference materials used will also be posted on Waterloo LEARN.

Laboratory: On-line with live demonstrations

The course had FOUR hardware labs, and one simulation lab. Due to current uncertainties from COVID-19, there are no in-person laboratory sessions. However, Labs 1, 2, and 3 will be carried out by Lab Instructor during the term, giving live demonstrations, and the experimental data are posted on Learn. Students are asked to analyse the data and submit reports. Lab 4 is a simulation study.

Students are encouraged to participate in attending the live demonstrations either on-line or in-person. The attendance for in-person lab is optional.

Lab 1: Generation and Measurement of AC, DC Voltages

Lab 2: Generation and Measurement of Impulse Voltages

Lab 3: Partial Discharge and Breakdown Studies

Lab 4: Electrostatic Analysis using COMSOL – Simulation Studies

Tutorials: On-line

Problems will be assigned on a weekly basis and will be posted on LEARN. The solutions for assigned problems will be posted after a week's time following the tutorials for that week. Additional assistance will be provided during the "office hours".

Evaluation:

The final grade will be based on the results of the mid-term test, quizzes, laboratory/simulation work, and take home exam. The weights for the different examination components are:

Mid Term Test: 20%, Quizzes: 20%, Laboratory/Simulation: 20% and Take home exam: 40%

Teaching Team:

People	Name	Room	Extension	E-mail address
Course Instructor	Shesha Jayaram	EIT 3105	35337	jayaram@uwaterloo.ca
Lab Instructor	Mohana Krishnan	CPH 1332	35017	m7krishnan@uwaterloo.ca
Teaching Assistant		To be announced		

Detailed Course Outline:

Part A: Generation and Measurement of High Voltages and Testing

No.	Topic	Sub-Topics
1	**Introduction**	• Power and Energy Systems • Importance of HV in power systems • HV transmission system - growth • HVAC and HVDC systems • Components of high voltage power system • Introduction to various insulation systems • Introduction to power system protection devices
2	**HV Generation for Testing**	• Origin of high voltage stresses • HV testing requirements • Test facilities • Destructive and non-destructive tests
3	**Generation of AC Voltages**	• AC power frequency sources • Special test transformers • Single and cascade transformers • AC resonant circuits
4	**Generation of DC Voltages**	• Special DC sources • Rectifier circuits • Voltage doubler • Voltage multiplier circuits • Electrostatic generators
5	**Generation of Impulse Voltages**	• Over voltages and transients • Basic impulse insulation levels • Lightning impulse • Switching impulse • Chopped impulse • Marx's principle • Impulse voltage generation and analysis • Multi stage impulse generators
6	**Measurement of DC, AC, and Impulse Voltages**	• Classification • Use of spark gaps • Clearance requirements • Use of standard test data and correction factors • Resistive dividers • Capacitive dividers • Mixed dividers • Low voltage arm measuring instruments

Part B: Basics of Conduction and Breakdown Mechanisms in Dielectrics

No.	Topics	Sub-Topics
7	**Gaseous insulation:**	• Source of charge carriers • High field conduction • Collision mechanisms and ionization • Primary and secondary processes • Breakdown theories; Townsend and Streamer • Impulse or surge breakdown • Statistical and formative time lags • Impulse time-volt characteristics • Visible corona; Corona inception and extinction • Positive corona, negative corona • Applications – overhead lines, GIS, breakers, etc. *GIS – gas insulated systems*
8	**Breakdown and Failure Mechanisms in Solids**	• Dielectric strength • Intrinsic breakdown • Electromechanical breakdown • Thermal equilibrium and breakdown • PD Detection methods • Discharge in cavities • Internal and surface discharges • Treeing and surface tracking • Applications – overhead lines, machines, cables, etc.
9	**Breakdown and Conduction Mechanisms in Liquids**	• Role of insulating liquids • Properties of insulating liquids • Source of charge carriers – role of impurities • Charge Injection and conduction • Breakdown theories • Cavitation/bubble theory • Suspended particle theory • Applications – transformers, cables, etc.

Part C: Insulation Coordination and Power System Protection

10	**Overvoltages and Insulation coordination**	• Causes of overvoltages; lightning, faults, switching • External and internal insulations • Lightning, switching and temporary overvoltages • Characteristics of overvoltages • Electric stress and electric strength • Clearances and withstand levels • Practices in insulation coordination • Pollution and environmental influence
11	**Overvoltage protection**	• Protective devices • Surge propagation and surge impedance • Surge protective device characteristics • Gapped silicon carbide arresters • Gapless metal oxide arresters • Time-voltage coordination
12	**Introduction to Overcurrent Protection**	• Basic definitions • Protection coordination • Aspects of power system protection • Faults in power systems • Types of faults • Protection coordination • Classification of protection relays: • Electromechanical, Solid-state or static relays
13	**Instrumentation Transformers**	• Current transformers (CTs) • CT Equivalent Circuit • CT_ saturation and accuracy • Voltage transformers (VTs) • Capacitively coupled voltage transformers CVTs
14	**System Protection Components**	• Relays • Circuit Breakers • Reclosers • Fuses • Disconnectors
15	**Overcurrent Protection Coordination**	• Building blocks of protection system • Principle of over current protection • Art and Science of Protection • Zones of protection • Primary and Backup • Protective devices and characteristics • Protection requirements • Coordinating over current devices • Time-dial setting • Time-current characteristic (TCC) curves • Coordination time intervals • Desirable Protection Attributes