

Department of Electrical and Computer Engineering University of Waterloo

ECE 665 - High Voltage Engineering Applications

Course Outline – Spring 2023

Course Instructor: Prof. E. A. Cherney
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Calendar Description:

The course begins with a general overview of testing and the various methods of generating and measuring high voltages and high currents in the laboratory and in the field. Since electrical insulation forms the foundation for all high voltage applications, the course focuses on the techniques to evaluate insulator designs that are exposed to various environmental stresses. New polymeric materials for electrical insulation in outdoor applications that are exposed to various environment conditions are reviewed with a focus on the effects of pollution and moisture on electrical insulation performance.

Renewable energy sources extensively use voltage source converters that generate fast transient voltages and these transients are a new type of stress on electrical insulation that are not always considered in insulation design. In addition, voltage converters are now extensively in use for powering electric automobiles, ships and soon air planes, to precise speed control medium high voltage motors for various industrial processes. The effects of these transient voltage on insulation design require special attention and the course focuses on the modifications to insulation designs that are required for satisfactory life.

The course ends with demonstrations in the high voltage laboratory, focusing on safety, clearances, test equipment, and methods.

Objectives:

- Study the theory of high voltage generation and measurements.
- Learn the operation of high voltage power supplies for ac, dc, and impulse voltages.
- Learn high voltage measurement techniques and testing.
- Get familiar with various applications where high voltage/high field is used.

References:

1. High Voltage Engineering – Fundamentals, 2nd Edition, E. Kuffel, W. S. Zaengl, and Kuffel, J. Oxford ; Boston : Newnes, 2000.
2. Advances in High Voltage Engineering: A. Haddad, D.F. Warne, Published by the Institution of Engineering & Tchnology, London, UK, 2004.
3. High Voltage Engineering; Practice and Theory by J.P. Holtzhausen and W.L. Vosloo, ISBN: 978 - 0 - 620 - 3767 - 7
4. Selected archival papers.

Prerequisites:

Basic knowledge of circuit analysis, and low voltage measurement techniques.

Basic knowledge of using MATLAB.

Familiarity with electrical power system components is useful.

ECE 665 Course Content

Lecture	Topic	Description
1	Generation of High Voltages for Testing	<ul style="list-style-type: none"> • Types and operation of various test sets including: single ended, cascade, and resonant AC, DC, lightning impulse and switching surge generators • Requirements of high voltage test equipment for various types of tests including: cables, gas insulated bus, power equipment and contamination testing • Grounding, limits of approach, safety considerations
2	Measurement of High Voltages	<ul style="list-style-type: none"> • Sphere gaps, potential dividers for ac, dc, impulse and switching surges • Measurement of very fast rise time pulses • Accuracy and sources of error in measurements • Digital recording
3	Testing Methods for Self-Restoring and Non-Restoring Insulation	<ul style="list-style-type: none"> • Up-and-down method for impulse and switching surge • Atmospheric correction factors • Wet and dry flashover at power frequency • Concept of Withstand • Withstand test methods for cables, SF₆ and equipment
4	Testing in the Field	<ul style="list-style-type: none"> • Cable commissioning tests • Rotating machine DC hi-pot and ramp test methods • Resonant testing of power cables and SF₆ equipment • Power factor and dissipation factor of bushings • Insulators
5	Measurement and Interpretation of Corona & Partial Discharges	<ul style="list-style-type: none"> • Introduction • Measurement circuits • Interpretation of discharge patterns • Diagnosis of origin of discharge
6	Control of Electric Fields	<ul style="list-style-type: none"> • Shaping conductors • Stress grading systems • Effects of transients from voltage converters
7	Understanding Outdoor Insulators and making them work	<ul style="list-style-type: none"> • Porcelain, toughened glass and polymer insulators • Design concepts, materials and manufacturing • Pollution flashover mechanism • Test methods • Performance enhancements
8	Cables	<ul style="list-style-type: none"> • Cable and cable accessories • Failure mechanisms • Cable life issues • Cable testing issues
9	Voltage Converters in Power Systems	<ul style="list-style-type: none"> • Rotating machine insulation • Cable terminations • Transformer insulation problems • Life testing
10	Insulation Co-ordination	<ul style="list-style-type: none"> • Surge arresters • BIL and SS • Insulation co-ordination between lines and stations • Distribution and transmission systems

11	Visit to High Voltage Laboratory	<ul style="list-style-type: none">• Discussion on clearances, grounding, safety aspects• Demonstration of impulse generator• Demonstration of power frequency test transformer, positive and negative corona, wet and polluted flashover of an insulator• Demonstration of DC test transformer• Demonstration of partial discharge testing• Demonstration of dissipation factor measurement
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Evaluation:

1. Short assignment under each topic for 35% of the final grade.
2. Mid-term research project for 25 % of the final grade.
3. Final exam for 40 % of the final grade.