UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG
SCHOOL OF ELECTRICAL AND INFORMATION ENGINEERING

ELEN4003 – High Voltage Engineering

Course Brief and Outline – 2019

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1 Course Background

High Voltage (HV) engineering is a final year elective course in the electrical engineering honours degree programme. In essence high voltage engineering entails application of fundamental knowledge and technics of mathematics, physics and chemistry in understanding and manipulating the interaction of electric fields with electrical insulation and dielectrics. The various concepts are discussed as they relate to typical HV equipment and instrumentation. In the field of electrical engineering, the efficient transfer of bulk electric power over long distances is one of the important functions of high voltage engineering technology. Although the Course is self-standing, it relates well to other courses such as power system engineering, electromechanical conversion (electric machines and drives), measurements and data science.

2 Course Objectives

This is an introductory course in the field of high voltage engineering. The course strives to equip students with the knowledge necessary to design, maintain and operate HV equipment by developing problem solving skills and analysis in the field. In the course, various case study problems are tackled. The students therefore get opportunities to develop skills in generic problem solving (**ELO 1**) as well as application of fundamental knowledge in developing solutions to engineering technology problems (**ELO 2**). In the project and laboratory components of the course, the students are inherently required to learn and demonstrate competencies in the use of specialized engineering tools such as electric field simulations (**ELO 5**). The individual course project report and laboratory reports are opportunities for students to learn and demonstrate competencies in technical communication skills (**ELO 6**).

Whilst successful completion of the course prepares the student for self-learning and development of engineering skills in the field, it also gives a solid foundation for further studies at higher academic levels in more specialized areas of high voltage engineering.

3 Course Outcomes

On successful completion of this course, the student is able to:

1. Derive the equations for electric stress enhancement in high voltage insulation defects,
2. Derive the equations for charge movement during the breakdown process in gases, liquids and solids,

3. Explain the physical process of electrical breakdown of gases; based on the Townsend, Streamer and leader models,
4. Compare and evaluate (by simple testing techniques) various insulation systems and materials - including the attaching and non-attaching gases (**ELO 5**),
5. Predict the breakdown voltage using appropriate calculations and electric field simulations in uniform and quasi-uniform fields in both attaching and non-attaching gases (**ELO 5**),
6. Describe and explain the standard HV tests, and design the test generator circuits for ac, dc and impulse voltages (and currents) (**ELO 1** and **ELO 2**),
7. Conduct selected HV tests, and be sensitised to basic HV experimental techniques and safety,
8. Produce concise laboratory and project reports to meet specific requirements in accordance with the *School's Blue Book* (**ELO 6**),
9. Define the standard test waveforms for selected HV tests,
10. Derive the performance equations for certain HV measurement systems (from dc through to systems to measure VFTs), and design these systems (**ELO 1**),
11. Critically evaluate technical papers presenting findings of investigation work in the field of HV engineering.

4 Course Content (knowledge areas)

The knowledge areas in the High Voltage course are summarized as follows:

1. **Electric fields:** Characteristics of electric fields; Field distribution calculations of typical electrode geometries.
2. **Conduction and breakdown mechanisms in gases:** Current flowing in a gas as a result of a single e-avalanche; the e-component of current, the negative ion component of current, the positive ion component of the current. Electrical breakdown in gases; Townsend mechanism of breakdown, Paschen's law, the streamer mechanism, the streamer mechanism in non-uniform field in air and SF6; The leader mechanism, lightning protection, breakdown under impulse voltages; time lags in breakdown process.
3. **Conduction and breakdown mechanisms in liquid insulation:** The intrinsic breakdown mechanisms; breakdown caused by impurities; failure caused by the presence of bubbles, failure caused by the presence of suspended particles.
4. **Breakdown mechanisms in solid insulation**: Intrinsic breakdown; electromechanical breakdown; electro-thermal breakdown, dielectric losses and measurements; breakdown initiated by impurities; breakdown initiated by electrical trees; breakdown due to partial discharges (PD); typical PD initiating defects, stress enhancement factors, understanding PD mechanisms.
5. **Generation of high voltage:** HVAC; cascaded HVAC transformers, Series resonance sources; HDVC; Greinacher voltage doubler circuit, Walton-Cockroft HVDC generator; impulse voltage generator; single stage impulse voltage generator, multiple stage (Marx) impulse voltage generator.
6. **Measurement of high voltage:** voltage dividers; electrostatic voltmeters.

5 Prior Knowledge Assumed

The following prior knowledge is assumed on the part of students starting this course:

1. Atomic structure, the quantum theory,
2. Principles of static electricity,
3. Molecular properties of matter and the gas laws,
4. Basic electric circuit theory,
5. Electrical laboratory techniques,
6. Engineering investigation techniques,
7. Knowledge on how to produce acceptable technical reports,

The prerequisites and co-requisites to register for this course are defined in the current *Rules & Syllabuses: Faculty of Engineering and the Built Environment*.

6 Assessment

6.1 Formative Assessments Elements

Each student produces a pre-laboratory report that is formatively assessed. The report should satisfy minimum prescribed standards as a condition for the student to proceed with conducting the laboratory experiments after which the student produces a lab report for summative assessment.

6.2 Summative Assessment

Table 1: Summative assessment contributions

Summative Assessment Contributor	Duration h	Component Yes/No	Method & Weight %	Calculator Type 0/1/2/3	Permitted Supporting Material
Laboratory exercise report	10	No	20	-	-
Course project report	30	No	30	-	-
Examination	3	No	50	2	Closed book Type 2 calculator + A4 sheet Crib sheet

6.2 Assessment Methods

Examination: In the exam, the students must demonstrate the ability to think critically and apply appropriate knowledge to provide appropriate and realistic solutions to the problems presented, some of which may be open-ended. The pass mark for the exam is 50%.

Project: The student must demonstrate the ability to systematically analyse and understand a problem, critically analyse, devise and validate solutions, and then communicate effectively through a technical report. The assessment of the project report is through use of a rubric of outcomes in which a single mark is derived from the level of achievement against the outcomes. The pass mark is at least 50% of the resultant mark.

The lab report: The student must demonstrate the ability to systematically analyse and understand an experimental problem, set up equipment and take measurements, critically analyse and discuss measurement results, and then communicate effectively through a technical report. The assessment of the laboratory exercise report is through use of a rubric of outcomes in which a single overall mark is derived from the level of achievement against the outcome. The pass mark is at least 50% of the resultant mark.

7 Satisfactory Performance (SP) Requirements

For the purpose of Rule G.13 *satisfactory performance in the work of the class* means attendance and completion of prescribed laboratory activities, attendance at tutorials designated as compulsory in this CB&O, submission of assignments, writing of scheduled tests unless excused in terms of due procedure.

8 Teaching and Learning Process

8.1 Teaching and Learning Approach

The basic material of the course is covered in lectures. The lectures are presented in a manner to catalyse the students’ engagement with the relevant sections and chapters in the course prescribed and recommended text books. Additional material will be handed out during the lectures as and when appropriate. The students are expected to undertake a significant amount of self-study in this course in order to gain a full understanding of the material. The laboratory exercises and the course project give the students an opportunity to develop skills in the practical application of the high voltage engineering knowledge. All material covered in lectures, labs and the class project is examinable.

8.2 Information to Support the Course

8.3 Learning Activities and Arrangements

Lectures: There is a double lecture session each week of which venue and time slots are as per the lecture timetables in the School of Electrical and Information Engineering.

Tutorials: Tutorial exercises will be appropriately embedded in the lecture sessions. Tutorial questions are available on the SAKAI Course website.

Project/Assignment: The course project brief document is issued out to the students in the first lecture. It will also be available for download on the SAKAI course website. The brief document presents the project specifications and assessment criteria. The submission deadline is specified including emphasis on the need to strictly adhere to the enforced School's policy on the timely submission of projects as per the *School's Red Book*. It is imperative that the students familiarize themselves with the School's policy on report submissions as specified in the *Red Book*. The project reports are submitted through a link provided at the Courses' SAKAI website.

Laboratory: Each student must complete two afternoon sessions in the Wits HV laboratory and submit a report for assessment. Eligibility to conduct the experiments in the HV laboratory is assessed through a preliminary report that each student has to produce and submit within specified deadlines. The course laboratory experiments brief document together with the timetable are made available for download on the SAKAI course website. The brief document presents the laboratory report specifications and assessment criteria. The submission deadlines are specified including emphasis on the need to strictly adhere to the enforced School's policy on the timely submission of projects as per the *School's Red Book*. The project reports are submitted through a link provided at the Courses' SAKAI website.

Consultation: Consultation time is normally the 15-minute break between the two double weekly lecture slots. If necessary, students are also free to request through email appointments for further consultations with the lecturer.

9 Course Home Page

Further information and announcements regarding the course are posted on the course home page: https://cle.wits.ac.za/portal/site/ELEN4003_2019

All students are expected to regularly consult the course home.