## Academic Course Description

King Saud University
Electrical Engineering Department

# EE446: High Voltage Engineering

**First Semester 1426/1427 (2005/2006)**

**Instructor:** **(1)** **Dr. A. A. Al- Arainy**
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**Text Books** A.A.Al-Arainy, M.I.Qureshi and N.H.Malik, " Fundamentals of High Voltage Engineering" King Saud University Press, 2005.

**References** M.S. Naidu and V. Kamaraju, "High Voltage Engineering", Second Edition, Tata McGraw Hill, India.
N.H.Malik, A.A.Al-Arainy and M.I.Qureshi, "Electrical Insulation in Power Systems", Marcel Dekker, New York, 1998.

**Pre-requisites:** EE340

**Co-requisites :** -- -- --

**Course Objectives:** To clearly understand the basic concepts of high voltage generation, measurement and testing techniques. Furthermore, the properties, applications and conduction and breakdown phenomena in various classes of insulation materials are discussed in this course.

**Topics Covered:** Types of high voltages and their applications. Generation of high DC, AC and impulse voltages. Measurements of high DC, AC and impulse voltages. Introduction to insulating materials and their uses. Breakdown mechanisms in gases, liquids and solids. High voltages test techniques and standards. Experiments on some selected topics are included as well.

**Class / Tutorial Schedule:** Three lectures are assigned per week with 50 minute for each lecture session. There is also a 50 minute weekly tutorial session associated with this course. Experiments are arranged within the assigned lecture sessions as well for some selected topics.

**Professional Component Contribution:** Students can learn the analytical methods and modern tools for solution of problems associated with power system design and operation with special emphasis on high voltage components used in generation, transmission and distribution systems. They acquire the basic skills of how to approach and deal with real life situations and solve simple simulated design and operating problems related to application of high voltage technology. Students must also utilize knowledge of mathematics, physics, circuits and basic engineering

sciences in order to effectively analyze a diverse set of fundamental problems in high voltage components and systems.

**Relationship to Program Objectives:** This course contributes to the general objectives listed for an Electrical Engineering Department.

**Objective A:** By teaching the student how to formulate basic problems and model the associated configurations, circuits and systems related to high voltage components and systems, this course support the objective of producing graduate with a strong foundation in basic sciences.

**Objective B:** By teaching students how to deal with high voltage systems and networks and solve basic problems related to generation, measurement and testing, the course helps in the department's production of students with a strong foundation in electrical engineering.

**Objective C:** By motivating and encouraging students in discussions during lectures and tutorials to get basic information and skills in a group environment and provide individual opinion on alternative solutions to the design and operating problem related to high voltage components and systems, this course supports the objective of producing graduate with good communication skills.

**Objective D:** By encouraging the students to learn pertinent ethical and professional standards in dealing with alternative methods and materials used for systems of energy generations, transmission and distribution, this course supports the objective of providing graduates with a broad based education so that they can appreciate diversity of opinion, better understand ethical issues and develop a more global perspective of the profession. In addition it highlights the impact of high voltage systems and components on the environment.

**Objective E:** By teaching how to design simple systems for generation, measurements and testing for a variety of components, this course supports the objective of producing graduates with relevant engineering design experience.

**Evaluation:** There are graded home works, two 2-hours mid-term exams and a three hour final exam. The grade distribution is as follows:

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| Two Mid-Term Exams. | 40% |
| Home Works, Quizzes, Lab Experiments & Class Participation | 15% |
| Final Exam | 40% |
| Total | 100% |

**Challenges and Actions taken to improve the Course:** Some basic background and pre-requisite type material are often reviewed during the course, notably those related to the review of basic power system components, and their functions. For teaching various topics in generation, measurement and testing experiments are arranged in the High Voltage Laboratory of the Electrical Engineering Department during the course in order to expose students to real life practical methods and enhance their knowledge of experimental techniques in high voltage engineering basics.

# Weekly Teaching Plan

| Week # | Deliverables |
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| 1 | Definitions of High Voltage, Classifications of High Voltages, Voltage levels used in Saudi Arabia, Types of High Voltages and their origins in power system, Uses of High Voltages, Reasons of using High Voltages in transmission systems, Selection of voltage level for transmission lines |
| 2 | Methods of High DC voltage generation circuits including half wave and full wave rectifiers, voltage doubler and voltage multiplier circuits and electrostatic generators. Definitions of ripple voltage, ripple factor and voltage drop, Methods to decrease the ripple in HVDC. Uses of HVDC. |
| 3 | Methods of High AC voltage generation including ordinary test transformers, Cascaded transformers, and resonance type AC power sources. Advantages, disadvantages and applications of each type. |
| 4-5 | Sources of surge voltages and their waveforms, Impulse voltages ; types, basic parameters, definitions of front time, time to half and peak value for lightning and switching impulses, Standard lightning and switching impulse waveforms, Single stage impulse generator circuits and their analysis, Design of generator to produce standard waveforms, Reasons of using multistage generator circuits, Multistage circuit, its working principle and analysis, Triggering of impulse generators, Special impulse generation circuits |
| 6-7 | Measurements of High Voltages using sphere-sphere gaps, peak voltmeters, electrostatic voltmeter, resistance in series with an ammeter, voltage transformer, capacitive voltage transformer, and voltage dividers. Detailed discussion about dividers for high DC, AC and Impulse voltages, divider ratio. Problems encountered when measuring EHV and UHV with dividers and solutions. Impulse measurement systems and measurement system response time and related issues. |
| 8 | High voltage insulation; reasons and areas of insulation applications, types of insulation materials and examples, desirable properties of various classes of insulation materials, thermal classifications of insulation, basic properties of insulation and related basic definitions |
| 9-10 | Breakdown in gases: Basic ionization processes, Townsend first and second ionization coefficients, current growth in uniform field gap due to primary and secondary processes, Townsend breakdown condition, Paschen Law and breakdown voltage characteristics, Breakdown voltages for air and SF6 gas insulation, Examples of insulation design for uniform and non uniform field gaps with air and SF6. Air breakdown under non uniform field conditions. Corona and corona onset voltage and corona onset field, effects of corona such as radio noise, audible noise, power loss, EMI, and static charging and methods to reduce corona on high voltage lines and other equipment. |
| 11 | Types of liquid insulation and uses, pure and commercial liquids, Conduction and breakdown in pure liquids, breakdown in commercial liquids and role of moisture, particles, gas bubbles, electrode surface defects and oil volume on breakdown, reconditioning of liquids |

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| 12-13 | Types of solids and breakdown in solid insulation materials including intrinsic breakdown, electromechanical breakdown, thermal breakdown, treeing and tracking and erosion. Partial discharges in solids, equivalent circuit and waveforms and effects of partial discharges |
| 14 | Non destructive testing including PD measurements and dissipation factor measurements. Destructive testing. Testing classifications and standards, Significance of testing in High Voltages |

September 19, 2005