CODE	COURSE NAME	CATEGORY	L	T	P	CREDITS
EET342	HIGH VOLTAGE ENGINEERING	PEC	2	1	0	3

Preamble: This course introduces basic terms and techniques applicable to high voltage ac and dc networks. Generation of different type of High voltage waveforms, their measurement and analysis including the insulation coordination of different equipments and machinery used in HV applications. It also provides a basic idea of FACTS devices and testing with the help of different testing circuits.

Prerequisite: Basics of Electrical Engineering / Introduction to Electrical Engineering

Course Outcomes: After the completion of the course the student will be able to:

CO 1	Identify different high voltage and current waveform generation circuits.
CO 2	Implement different sensing & measurement techniques for high voltage and current measurement
CO 3	Describe insulation coordination and surge arrestor design
CO 4	Interpret different FACTS devices and their application in HV systems
CO 5	Implement different testing methods for equipments and applications of HV systems

Mapping of course outcomes with programoutcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	3										2
CO 2	3	3										2
CO 3	3	3					2					2
CO 4	3	3					2					2
CO 5	3	3					2					2

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember (K1)	10	10	10
Understand (K2)	20	20	40
Apply (K3)	20	20	50
Analyse (K4)	-	-	-
Evaluate (K5)	-	-	-
Create (K6)	-	-	-

End Semester Examination Pattern : There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain generation of high voltage AC, DC, impulse voltage and impulse current (K2)
2. Problems on high voltage generator circuits (K2, K3)

Course Outcome 2 (CO2):

1. Explain HV measurement techniques including measurement of peak and rms values (K2)
2. Explain dielectric measurements and partial discharge measurements (K2)
3. Problems on different HV measurement techniques (K2, K3)

Course Outcome 3 (CO3):

1. Explain procedure of insulation coordination (K2)
2. Selection criterion of surge arrester (K2, K3)

Course Outcome 4 (CO4):

1. Describes general principles and main components of HVDC system (K2, K3)
2. Explain FACTS devices used in HV systems (K2)

Course Outcome 5 (CO5):

1. Interpret the testing methods of various components (K2,K3)
2. Explains the applications of HV in various fields (K2)

Model Question paper

QP CODE:

PAGES:2

Reg. .No:_____

Name:_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SIXTH SEMESTER B. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: EET342

Course Name: HIGH VOLTAGE ENGINEERING

Max. Marks: 100 Duration: 3 Hours

PART A (3 x 10 = 30 Marks)

Answer all Questions. Each question carries 3 Marks

1. Explain the principle of impulse current generation
2. Explain the working of Cockcroft-Walton voltage multiplier circuit
3. State the different factors affecting the spark over voltage of sphere gap
4. Differentiate between internal and external partial discharges
5. Explain the role of surge arrestors
6. Explain insulation coordination
7. With the help of diagram explain the working of SVC and UPFC
8. State the main components of HVDC links
9. Explain the field testing of HV transformer bushings
10. Explain the objectives of High voltage testing

PART B (14 x 5 = 70 Marks)

Answer any one full question from each module. Each question carries 14 Marks

Module 1

11. a)With the help of diagram explain the generation of rectangular current pulses **(10)**
    b)Explain impulse current generator. **(4)**
12. a) Explain the construction and operation of Marx circuit for multistage impulse generation **(10)**
    b) Discuss the working principle of series resonant circuit used for the generation of high voltage AC **(4)**

Module 2

13. a)Explain how a sphere gap can be used for the measurement of peak voltages **(10)**
    b)Explain the working principle of generating voltmeter. **(4)**

14. a) Explain the operation of Rogowski coil and how it is used for the measurement of high impulse currents. **(10)**
    b) Discuss the disadvantages of sphere gap measurement. **(4)**

Module 3

15. a) Explain how a lightning arrestor location is selected and the rating of the arrestor is selected **(10)**
    b) Differentiate between surge absorber and diverter **(4)**

16. a) An overhead line having surge impedance of 400ohms bifurcates into two lines having surge impedances 400ohm and 40 ohms respectively. Calculate the values of voltage and current for bifurcated lines if a surge voltage of 20kV incidence on the OH line **(10)**
    b) Explain the role of surge arrestor as a shunt protective device. **(4)**

Module 4

17. Elaborate on the main components of HVDC links **(14)**
18. Explain in detail the principle and operation of series compensator andSTATCOM **(14)**

Module 5

19. a) Give a detailed note on insulation systems for impulse voltages **(7)**
    b)Describe in detail electrostatic particle precipitation **(7)**

20. a) Explain any one method of non-disruptive testing for early detection of insulation faults **(4)**
    b)List the various tests performed on high voltage cables **(10)**

Syllabus

Module 1

Generation of High Voltage and Currents

Generation of High DC and AC Voltages- half-wave rectifier circuit- Cockroft-Walton voltage multiplier circuit- Electrostatic generator- Generation of high AC voltages-Cascaded Transformers- Series resonant circuit

Generation of Impulse Voltages and Currents- Impulse voltage- Impulse generator circuits-Multistage impulse generator circuit- Construction of impulse generator- Triggering of impulse generator-Impulse current generation

Module 2

HV measuring techniques

High Voltage Measurement Techniques -Measuring Spark Gaps - Sphere-to-sphere Spark Gap -Rod-to-rod Spark Gap - Electrostatic Voltmeter- Field Sensors - Electrically Short Sensors, Electrically Long Sensors, Potential-free Probes, Generator-mode Sensors, Electro-optical and Magneto-optical Field Sensors - Voltage Dividers - Instrument Transformers - Measurements of R.M.S. Value, Peak Value and Harmonics - Current Measurement

Dielectric measurements- Dissipation Factor and Capacitance, Insulation Resistance, Conductivity, Dielectric System Response-Partial discharge measuring technique-Requirements on a partial discharge measuring system - Measuring systems for apparent charge – Partial discharge measurements on high-voltage transformers, high-voltage cables, high-voltage gas-insulated substations

Module 3

Insulation Coordination and surge arresters

Classification of Voltages and Overvoltages-Origin of Overvoltages – Representative Overvoltages- Performance Criterion –Withstand voltage.

Insulation Coordination Procedure- Determination of Representative Voltages and Overvoltages-Continuous Power Frequency Voltage, Temporary Overvoltages, Slow-Front Overvoltages, Fast-Front Overvoltages

Determination of Coordination Withstand Voltage (Ucw)-Deterministic Approach, Statistical Approach: Risk of Failure - Determination of Required Withstand Voltage (Urw)-Altitude Correction Factor, Safety Factor (Ks)- Selection of Standard Withstand Voltage (Uw)- Surge Arresters- Rated Voltage- Discharge Current- Impulse Current Tests- Residual Voltages-Arrester Durability Requirements

Module 4

HVDC and FACTS

HVDC transmission –General principles-VSC HVDC-Main components of HVDC links-Thyristor valves, Converter transformer, Control equipment, AC filters and reactive power control, Smoothing reactor and DC filter, Switchgear, Surge arresters, Valve cooling, Auxiliary supplies

Converter building - Power electronic support for AC systems- Static var compensators (SVCs), STATCOM, Series compensators, Unified power flow controller (UPFC)

Module 5

Testing of HV Systems

High voltage Testing of insulators, bushings, isolators, circuit breakers, transformers, surge diverters, cables

Insulation Systems for AC Voltages -Cables, bushings and transformers-Insulation Systems for DC Voltages- Capacitors, HVDC bushings and Cables-Insulation Systems for Impulse Voltages -Electrical Stress and Strength -Energy Storage -Impulse Capacitors (Energy Storage or Surge Capacitors)

Lightning Protection- Light and Laser Technology- X-ray Technology-Electrostatic Particle Precipitation, Ionization- Spark plugs

Text Books

1. C L Wadhwa, "High Voltage Engineering", New Age International Publishers, 2011.
2. Andreas Kuchler, " High Voltage Engineering Fundamentals – Technology – Applications", Springer, 2018

References:

1. Naidu M.S. and Kamaraju V., “High voltage Engineering”, Tata McGraw Hill Publishing Company Ltd., New Delhi, 2004.
2. Farouk A.M. Rizk&Giao N. Trinh, “High Voltage Engineering”, CRC Press, 2014.
3. Kuffel, E., Zaengl, W.S. and Kuffel J., “High Voltage Engineering Fundamentals”, Elsvier India P Ltd, 2005.
4. Hugh M. Ryan, “High-Voltage Engineering and Testing”, IET Power and energy series, 2013.
5. N.G. Hingorani and L.Gyugyi,“Understanding FACTS”,IEEE Press, 2000.

Course Contents and Lecture Schedule:

No	Topic	No. of Lectures
1	**Generation of High Voltage and Currents(7 hours)**	
1.1	Generation of High DC and AC Voltages- half-wave rectifier circuit- Cockcroft-Walton voltage multiplier circuit	2
1.2	Electrostatic generator- Generation of high AC voltages-Cascaded Transformers - Series resonant circuit	2
1.3	Generation of Impulse Voltages and Currents- Impulse voltage- Impulse generator circuits	1
1.4	Multistage impulse generator circuit- Construction of impulse generator- Triggering of impulse generator-Impulse current generation	2
2	**HV measuring techniques (7hours)**	
2.1	High Voltage Measurement Techniques -Measuring Spark Gaps - Sphere-to-sphere Spark Gap -Rod-to-rod Spark Gap	1
2.2	Electrostatic Voltmeter- Field Sensors - Electrically Short Sensors, Electrically Long Sensors, Potential-free Probes, Generator-mode Sensors, Electro-optical and Magneto-optical Field Sensors	1
2.3	Voltage Dividers - Instrument Transformers - Measurements of R.m.s. Value, Peak Value and Harmonics - Current Measurement	2
2.4	Dielectric measurements- Dissipation Factor and Capacitance, Insulation Resistance, Conductivity,	1
2.5	Dielectric System Response-Partial discharge measuring technique- Requirements on a partial discharge measuring system	1
2.6	Measuring systems for apparent charge – Partial discharge measurements on high-voltage transformers, high-voltage cables, high-voltage gas-insulated substations	1
3	**Insulation Coordination and surge arresters(8 Hours)**	
3.1	Classification of Voltages and Overvoltages-Origin of Overvoltages – Representative Overvoltages- Performance Criterion –Withstand voltage.	2
3.2	Insulation Coordination Procedure- Determination of Representative Voltages and Overvoltages-Continuous Power Frequency Voltage, Temporary Overvoltages, Slow-Front Overvoltages, Fast-Front Overvoltages	2

3.3	Determination of Coordination Withstand Voltage (Ucw)-Deterministic Approach, Statistical Approach: Risk of Failure - Determination of Required Withstand Voltage (Urw)-Altitude Correction Factor, Safety Factor (Ks)- Selection of Standard Withstand Voltage (Uw)	2
3.4	Surge Arresters- Rated Voltage- Discharge Current- Impulse Current Tests- Residual Voltages-Arrester Durability Requirements	2
4	**HVDC and FACTS (6 Hours)**	
4.1	HVDC transmission –General principles-VSC HVDC -Main components of HVDC links- Thyristor valves, Converter transformer,	2
4.2	Control equipment, AC filters and reactive power control, Smoothing reactor and DC filter, Switchgear, Surge arresters, Valve cooling, Auxiliary supplies	2
4.3	Converter building - Power electronic support for AC systems- Static var compensators (SVCs), STATCOM, Series compensators, Unified power flow controller (UPFC)	2
5	**Testing of HV Systems (8 Hours)**	
5.1	High voltage Testing of insulators, bushings, isolators, circuit breakers, transformers, surge diverters, cables	2
5.2	Insulation Systems for AC Voltages -Cables, bushings and transformers- Insulation Systems for DC Voltages- Capacitors	2
5.3	HVDC bushings and Cables-Insulation Systems for Impulse Voltages - Electrical Stress and Strength-Energy Storage -Impulse Capacitors (Energy Storage or Surge Capacitors)	2
5.4	Applications-Lightning Protection- Light and Laser Technology- X-ray Technology-Electrostatic Particle Precipitation, Ionization- Spark plugs	2