

CODE	COURSE NAME	CATEGORY	L	T	P	CREDITS
EET466	HVDC AND FACTS	PEC	2	1	0	3

**Preamble:** This course introduces HVDC concepts and analysis of HVDC systems. It also provides a detailed study of FACTS devices.

**Prerequisite :** Nil

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

<b>CO 1</b>	Analyse current source and voltage source converters for HVDC systems
<b>CO 2</b>	Describe the control schemes for HVDC systems
<b>CO 3</b>	Explain the need for FACTS devices
<b>CO 4</b>	Classify reactive power compensators in power system
<b>CO 5</b>	Interpret series and shunt connected FACTS devices for power system applications
<b>CO 6</b>	Explain the dynamic interconnection mechanisms of FACTS devices

#### Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
<b>CO 1</b>	3	3			2							
<b>CO 2</b>	3	3			2							
<b>CO 3</b>	3	3			2							
<b>CO 4</b>	3	3			2							
<b>CO 5</b>	3	3			2							
<b>CO 6</b>	3	3			2							

#### Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember (K1)	20	20	40
Understand (K2)	20	20	40
Apply (K3)	10	10	20
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. Discuss the advantages of HVDC over HVAC (K2, PO1)
2. Explain various types of HVDC system (K2, PO1)
3. Explain various converters in HVDC system(K2, PO2)

#### **Course Outcome 2 (CO2):**

1. Discuss the control basics of two terminal link (K2, PO1)
2. Explain static  $V_d-I_d$  characteristics of a HVDC system (K2, PO1)
3. Derive equivalent circuit of a two terminal HVDC link (K3, PO2)

#### **Course Outcome 3 (CO3):**

1. What is meant by voltage regulation? (K1,PO1, PO2)
2. With neat diagrams explain the effect of phase angle compensation (K2,PO1,PO2)

#### **Course Outcome 4 (CO4):**

1. Explain the principle of TSC. Also explain the effect of initial charge of the capacitor in TSC. (K2, PO1, PO2)
2. Explain the principle and operation of STATCOM(K2, PO1, PO2)

#### **Course Outcome 5 (CO5):**

1. Explain with a neat circuit and necessary waveforms, the operation of IPFC. (K2, PO1,PO2)
2. Explain the applications UPFC (K2, PO1)

**Model Question Paper****QP CODE:**

PAGES: 2

Reg. .No: \_\_\_\_\_

Name: \_\_\_\_\_

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

**Course Code: EET466**

**Course Name: HVDC AND FACTS**

Max. Marks: 100

Duration: 3 Hours

**PART A (3 x 10 = 30 Marks)**

**Answer all Questions. Each question carries 3 Marks**

1. Explain the advantages of HVDC transmission system over HVAC.
2. What will be the effect on the Short Circuit MVA of a bus if an additional HVDC line is connected to that bus?
3. Enumerate the functions of HVDC control.
4. Discuss any one method for extinction angle control in HVDC.
5. Why are FACTS controllers needed in AC power transmission systems?
6. Explain the effect of series compensation
7. Explain TSR controller with necessary waveforms
8. Explain with neat circuit and necessary waveforms, the operation of TSSC
9. Give the comparisons between UPFC and IPFC
10. Explain the working principle of Thyristor Controlled phase angle Regulator

**PART B (14 x 5 = 70 Marks)**

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

**Module 1**

11. a) Derive average output voltage of a 6 pulse converter with overlap **(10)**  
b) Compare CSC and VSC. **(4)**
12. a) Explain VSC with AC voltage control with the help of schematic. **(10)**  
b) Discuss the effect of delay angle in the reactive power requirement, in a HVDC system. **(4)**

**Module 2**

- 13 a) Derive equivalent circuit of a two terminal HVDC link (10)  
 b) Explain the hierarchy of controls in HVDC system. (4)
- 14 a) Explain static  $V_d-I_d$  characteristics of a HVDC system. (10)  
 b) Draw the schematic of current control at the rectifier end. (4)

**Module 3**

- 15 a) Explain the effect of shunt compensation with neat diagrams (8)  
 b) Give the comparisons between series and shunt compensators (6)
- 16 a) What is meant by power quality and voltage regulation?  
 Explain its significance in power systems (10)
- b) List out different types of FACTS controllers. (4)

**Module 4**

17. Explain TCR controller. What are the different methods to eliminate harmonics? (14)
18. (a) Explain the principle and operation of SSSC compensation (4)  
 (b) Explain with diagrams, the different modes of TCSC controller (10)

**Module 5**

- 19.a) With neat diagram, explain the modes of operation of UPFC (8)  
 b) Explain with neat circuit, the operation of IPFC (6)
- 20.a) Explain the working principle of Thyristor Controlled Voltage e Regulator (4)  
 b) Explain the independent reactive power flow control (P&Q) characteristic of UPFC (10)



## Syllabus

### Module 1

#### Introduction to HVDC System

Comparison of AC and DC Transmission - Types of HVDC system - Current Source Converters - Analysis without and with overlap period. Voltage Source Converters (VSC) - VSC with AC current control and VSC with AC voltage control

### Module 2

HVDC Controls - Functions of HVDC Controls - Equivalent circuit for a two terminal DC Link - Control Basics for a two terminal DC Link - Current Margin Control Method - Current Control at the Rectifier - Inverter Extinction Angle Control - Hierarchy of Controls

### Module 3

#### Introduction to FACTS

Power flow in Power Systems – Voltage regulation and reactive power flow control in Power Systems - Power flow control -Constraints of maximum transmission line loading - Needs and emergence of FACTS - Types of FACTS controllers-Advantages and disadvantages

Transmission line compensation- Uncompensated line -shunt compensation - Series compensation -Phase angle control.

### Module 4

#### Shunt and Series Facts Devices

Static shunt Compensator - Objectives of shunt compensations - Variable impedance type VAR Generators -TCR, TSR, TSC, FC-TCR (Principle of operation and schematic) and -STATCOM (Principle of operation and schematic).

Static Series compensator - Objectives of series compensations-Variable impedance type series compensators - GCSC, TCSC, TSSC (Principle of operation and schematic)

Switching converter type Series Compensators-(SSSC) (Principle of operation and schematic)

### Module 5

#### UPFC AND IPFC

Unified Power Flow Controller: Circuit Arrangement, Operation of UPFC- Basic principle of P and Q control- independent real and reactive power flow control- Applications

Introduction to interline power flow controller (IPFC) (Principle of operation and schematic)

Thyristor controlled Voltage and Phase angle Regulators (Principle of operation and schematic)

*Note: Simulation assignments may be given in MATLAB, SCILAB, PSAT, ETAP, PSCAD, etc.*

**Text Books**

1. Vijay K Sood, “HVDC and FACTS Controllers”, Springer, 2004
2. N.G. Hingorani and L.Gyugyi, “Understanding FACTS”, IEEE Press 2000

**References:**

1. K.R.Padiyar, “High Voltage DC Transmission”, Wiley 1993
2. Y.H. Song and A.T.Jones, “Flexible AC Transmission systems (FACTS)”, IEEE Press 1999.
3. K.R.Padiyar, “FACTS Controllers in Power Transmission and distribution”, New age international Publishers 2007.
4. T.J.E. Miller, “Reactive Power control in Power systems”, John Wiley 1982.
5. C.L.Wadhwa, “Electric Power Systems”, New Academic Science Limited, 1992



**Course Contents and Lecture Schedule:**

No	Topic	No. of Lectures
<b>1</b>	<b>HVDC Converters(6 hours)</b>	
1.1	Comparison of AC and DC Transmission Systems - Costs, Technical considerations and reliability	1
1.2	Types of HVDC Links	1
1.3	Current Source Converters	2
1.4	Voltage Source Converters	2
<b>2</b>	<b>HVDC Controls (7 hours)</b>	
2.1	Function of HVDC Controls	1
2.2	Control Basics of two terminal DC Link	2
2.3	Current Margin Control Method	1
2.4	Current Control at the rectifier	1
2.5	Inverter Extinction Angle Control	1
2.6	Hierarchy of Controls	1
<b>3</b>	<b>Introduction to FACTS (6 hours)</b>	
3.1	Power flow in Power Systems – Voltage regulation and reactive power flow control in Power Systems - Power flow control -Constraints of maximum transmission line loading	2
3.2	Needs, emergence of FACTS- Types of FACTS controllers-Advantages and disadvantages	2
3.3	Transmission line compensation- Uncompensated line shunt compensation - Series compensation -Phase angle control. (line diagram, vector diagram and expression for P and Q)	2
<b>4</b>	<b>Shunt and Series Facts Devices (8 Hours)</b>	
4.1	Static shunt Compensator - Objectives of shunt compensations,	1
4.2	Variable impedance type VAR Generators -TCR , TSR, TSC, FC-TCR (Principle of operation and schematic)	2
4.3	STATCOM- Principle of operation-and schematic	1

4.4	Static Series compensator - Objectives of series compensations	1
4.5	Variable impedance type series compensators - GCSC, TCSC, TSSC - Principle of operation and schematic	2
4.6	Switching converter type Series Compensators-(SSSC)- Principle of operation and schematic	1
<b>5</b>	<b>UPFC AND IPFC (7 Hours)</b>	
5.1	Unified Power Flow Controller: Circuit Arrangement, Operation of UPFC-	2
5.2	Basic principle of P and Q control- independent real and reactive power flow control- Applications	2
5.3	Introduction to interline power flow controller (IPFC).	1
5.4	Thyristor controlled Voltage and Phase angle Regulators -Principle of operation	2

