

# HVDC TRANSMISSION

Subject Code : EE722PE

Regulations : R16 - JNTUH

Class : IV Year B.Tech EEE I Semester



**Department of Electrical and Electronics and Engineering**

**BHARAT INSTITUTE OF ENGINEERING AND TECHNOLOGY**

Ibrahimpattanam - 501 510, Hyderabad.

## HVDC TRANSMISSION (EE722PE)

### COURSE PLANNER

<b>Course Title</b>	HVDC TRANSMISSION			
<b>Course Code</b>	EE722PE			
<b>Class</b>	B.Tech. IV Year I Semester EEE			
<b>Regulations</b>	JNTUH - R16			
<b>Course Structure</b>	Lectures	Tutorials /Bridge	Practical	Credits
	3	1	-	4
<b>Course Coordinator</b>	Mr.G.Kamalaker Reddy, Assistant Professor			
<b>Team of Instructors</b>	Mr. G.Kamalaker Reddy, Assistant Professor			
	Mr. K .MurugaperumalAssistant Professor			

#### **I. COURSEOVERVIEW:**

This subject deals with importance of HVDC transmission, analysis of HVDC converters, Harmonics and filters, reactive power control and power factor improvement of the system.

This course provides

- The foundations of high voltageDC transmission in the Power systems.
- Topics include basics of converters, system control and power flow analysis, harmonics and filters

#### **II. PREREQUISITE(S)**

<b>Level</b>	<b>Credits</b>	<b>Periods/ Week</b>	<b>Prerequisites</b>
UG	4	4	Power Systems Power Electronics

#### **III. COURSEOBJECTIVES:**

At the end of the course, the students will be able to:

- To compare EHV AC and HVDC systems and various Types of DC links
- To analyze Graetz circuit with different mode of operations
- To control HVDC systems through various methods of AC/DC power flow study
- To describe various protection methods for HVDC systems and Harmonics reduce filter design.

#### IV. COURSE OUTCOMES:

After completing this course the student must demonstrate the knowledge and ability to:

S. No.	Course Outcomes (CO)	Knowledge Level (Blooms Level)
CO1	Distinguish between EHV AC and HVDC systems and various types of DC links.	L2: UNDERSTAND
CO2	Design the Graetz circuit with different mode of operations	L4: ANALYZE
CO3	Generalize the importance of HVDC converters, AC/DC Power flow and its reactive power control techniques	L2: UNDERSTAND
CO4	Compute various converter's faults and its protections	L3: APPLY
CO5	Design the harmonics reduction filters for HVDC transmission	L4: ANALYZE

#### V. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes (PO)		Level	Proficiency assessed by
PO1	<b>Engineering knowledge:</b> Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems related to Electrical and Electronics Engineering.	3	Assignments
PO2	<b>Problem analysis:</b> Identify, formulate, review research literature, and analyze complex engineering problems related Electrical and Electronics Engineering and reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	3	Open ended experiments /
PO3	<b>Design/development of solutions:</b> Design solutions for complex engineering problems related Electrical and Electronics Engineering and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	2	Assignments
PO4	<b>Conduct investigations of complex problems:</b> Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data,	----	-----

Program Outcomes (PO)		Level	Proficiency assessed by
	and synthesis of the information to provide valid conclusions.		
PO5	<b>Modern tool usage:</b> Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.	----	-----
PO6	<b>The engineer and society:</b> Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the Electrical and Electronics Engineering professional engineering practice.	1	Case study Analysis
PO7	<b>Environment and sustainability:</b> Understand the impact of the Electrical and Electronics Engineering professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.	----	-----
PO8	<b>Ethics:</b> Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.	----	-----
PO9	<b>Individual and team work:</b> Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.	----	-----
PO10	<b>Communication:</b> Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.	----	-----
PO11	<b>Project management and finance:</b> Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.	----	-----

Program Outcomes (PO)		Level	Proficiency assessed by
PO12	<b>Life-long learning:</b> Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.	1	Competitive Examinations

1:Slight(Low)      2:Moderate(Medium)      3:Substantial(High)      - :None

#### VI. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes (PSO)		Level	Proficiency assessed by
PSO1	Talented to analyze, design, and implement electrical & electronics systems and deal with the rapid pace of industrial innovations and developments.	2	Lectures/ Assignments/ NPTEL
PSO2	Skillful to use application and control techniques for research and advanced studies in Electrical & Electronics Engineering domain.	2	Mini Projects / Simulation

1: Slight (Low)      2: Moderate (Medium)      3: Substantial (High)      - : None

#### VII. SYLLABUS:

##### UNIT – I

**Basic Concepts:** Necessity of HVDC systems, Economics and Terminal equipment of HVDC transmission systems, Types of HVDC Links, Apparatus required for HVDC Systems, Comparison of AC and DC Transmission, Application of DC Transmission System, Planning and Modern trends in D.C. Transmission.

**Analysis of HVDC Converters:** Choice of Converter Configuration, Analysis of Graetz circuit, Characteristics of 6 Pulse and 12 Pulse converters, Cases of two 3 phase converters in Y/Y mode – their performance.

## **UNIT – II**

**Converter and HVDC System Control:** Principle of DC Link Control, Converters Control Characteristics, Firing angle control, Current and extinction angle control, Effect of source inductance on the system, Starting and stopping of DC link, Power Control.

**Reactive Power Control In HVDC:** Introduction, Reactive Power Requirements in steady state, sources of reactive power- Static VAR Compensators, Reactive power control during transients.

## **UNIT – III**

**Power Flow Analysis in AC/DC Systems:** Modeling of DC Links, DC Network, DC Converter, Controller Equations, Solution of DC load flow, P.U. System for DC quantities, solution of AC-DC Power flow- Simultaneous method-Sequential method.

## **UNIT – IV**

**Converter Faults and Protection:** Converter faults, protection against over current and over voltage in converter station, surge arresters, smoothing reactors, DC breakers, Audible noise, space charge field, corona effects on DC lines, Radio interference.

## **UNIT – V**

**Harmonics:** Generation of Harmonics, Characteristics harmonics, calculation of AC Harmonics, Non-Characteristics harmonics, adverse effects of harmonics, Calculation of voltage and Current harmonics, Effect of Pulse number on harmonics **Filters:** Types of AC filters, Design of Single tuned filters –Design of High pass filters.

### **TEXT BOOKS:**

1. “K. R. Padiyar”, HVDC Power Transmission Systems: Technology and system Interactions, New Age International (P) Limited, and Publishers, 1990.
2. “S K Kamakshaiah, V Kamaraju”, HVDC Transmission, TMH Publishers, 2011

3. "S. Rao", EHVAC and HVDC Transmission Engineering and Practice, Khanna publications, 3rd Edition 1999.

**REFERENCE BOOKS:**

1. "Jos Arrillaga", HVDC Transmission, The institution of electrical engineers, IEE power & energy series 29, 2nd edition 1998.
2. "E. W. Kimbark", Direct Current Transmission, John Wiley and Sons, volume 1, 1971.
3. "E. Uhlmann", Power Transmission by Direct Current, B. S. Publications, 2009

**NPTEL Video Lectures**

1. <https://nptel.ac.in/courses/108104013/>
2. <https://nptel.ac.in/courses/108104013/1>
3. <https://nptel.ac.in/courses/108104013/2>
4. <https://nptel.ac.in/courses/108104013/3>
5. <https://nptel.ac.in/courses/108104013/4>
6. <https://nptel.ac.in/courses/108104013/5>
7. <https://nptel.ac.in/courses/108104013/6>
8. <https://nptel.ac.in/courses/108104013/7>
9. <https://nptel.ac.in/courses/108104013/8>
10. <https://nptel.ac.in/courses/108104013/9>

**VIII. COURSEPLAN:**

At the end of the course, the students are able to achieve the following course learning outcomes:

Lecture no	week	Unit no	Topics to be covered	course Learning Outcomes	Teaching Methodologies	References
1	1		Necessity of HVDC systems	Able to understand the EHV and DC transmission merits and drawbacks	chalk & talk	T1, R2
2.			Economics and Terminal equipment of HVDC transmission systems.		chalk & talk	T1, R2
3.			Types of HVDC Links, Apparatus required for HVDC Systems.		chalk & talk	T1, R2

4.			Comparison of AC and DC <u>Transmission. Application of HVDC</u>		chalk & talk	T1, R2
5.	2		Planning and Modern trends in D.C. <u>Transmission.</u>		chalk & talk	T1, R2
6.			Choice of Converter Configuration	Able to design basic Graets circuit and analysing of its performance	chalk & talk	T1, R2
7.			Analysis of Graetz circuit, <u>Characteristics of 6 Pulse and 12</u>		chalk & talk	T1, R2
8.		1	<u>Characteristics of 6 Pulse and 12</u> <u>Pulse converters</u>		PPT	T1, R2
9.	3		Two 3 phase converters in Y/Y mode		chalk & talk	T1, R2
10.			Y/Y mode performance		chalk & talk	T1, R2
<b>MOCK TEST I</b>						
11.		2	Principle of DC Link Control	Able to understand about different control techniques of HVDC system	chalk & talk	T1, R2
12.			Converters Control Characteristics,		chalk & talk	T1, R2
13.	4		Firing angle control		chalk & talk	T1,T2
14.			Current and extinction angle control		chalk & talk	T1,T2
			Effect of source inductance on the system	Able to understand about DC link characteristics	chalk & talk	T1,T2
			Starting and stopping of DC link and Power Control		chalk & talk	T1,T2
16.	5		Introduction about Reactive Power <u>Requirements</u>		chalk & talk	T1,T2
18.			sources of reactive power	PPT	T1,T2	
19.			Static VAR Compensators	Able to understand about VAR compensators	chalk & talk	T1,T2
20.			Reactive power control during transients		chalk & talk	T1,T2
21.	6	3	Modelling of DC Links	Able to analysis the modelling of DC links and load flows	chalk & talk	T1,T2
22.			Modelling of DC Links		chalk & talk	T1,T2
23.			DC Network, DC Converter		chalk & talk	T1,T2
24.			Controller Equations		chalk & talk	T1,T2
25.	7		Solution of DC load flow,		chalk & talk	T1,T2
26.			Solution of DC load flow,		PPT	NTPEL
			P.U. System for DC quantities	chalk & talk	T1,T2	
			solution of AC-DC Power flow <u>Simultaneous method</u>	Able to develop the	chalk & talk	T1,T2



	8		Solution of AC-DC Power flow - <u>Sequential method.</u>	solution for AC-DC power flow	chalk & talk	T1,T2
30.			Comparison between Simultaneous method and Sequential method.		chalk & talk	T1,T2
31.		4	Intro about Converter faults,	Able to identify the converter faults	PPT	T1,T2
32.			Converter faults,		chalk & talk	T1,T2
33.	9		protection against over current and <u>over voltage in converter station</u>	Able to understand the HVDC link protection methods	chalk & talk	T1,T3
			protection against over current and <u>over voltage in converter station</u>		chalk & talk	T1,T3
35.			surge arresters, smoothing reactors		chalk & talk	T1,T3
36.			smoothing reactors, DC breakers		chalk & talk	T1,T3
37.	10		Audible noise, space charge field		chalk & talk	T1,T3
38.			corona effects on DC lines		chalk & talk	T1,T3
			<b>MOCK TEST II</b>			
39.			Radio interference	chalk & talk	T1,T3	
40.		5	<b>Intro Harmonics</b>	Able to understand different types of Harmonics and its behaviours.	PPT	NTPEL
41.	11		Generation of Harmonics		chalk & talk	T1,R2
42.			Characteristics harmonics		chalk & talk	T1,R2
			calculation of AC Harmonics		chalk & talk	T1,R2
			calculation of AC Harmonics		chalk & talk	T1,R2
45.	12		Non- Characteristics harmonics		chalk & talk	T1,R2
46.			adverse effects of harmonics		chalk & talk	T1,R2
			Calculation of voltage and Current <u>harmonics</u>		chalk & talk	T1,R2
48.			Calculation of voltage and Current <u>harmonics</u>		chalk & talk	T1,R2
49.	13		Effect of Pulse number on harmonics		chalk & talk	T1,R2
50.			<b>Filters:</b> Types of AC filters	Able to design different filters circuits for HVDC transmission	chalk & talk	T1,R2
51.			Design of Single tuned filters		chalk & talk	T1,R2
52.			Design of Single tuned filters		chalk & talk	T1,R2
53.	14		Design of High passes filters.		chalk & talk	T1,R2
54.			Design of High passes filters.		chalk & talk	T1,R2
55.			<b>HVDC transmission advancements</b>		Case study analysis	-

**IX. MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

Course Outcomes	Program Outcomes (PO)												Program Specific Outcomes (PSO)	
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	2			1						1	2	2
CO2	3	3	2			1						1	2	2
CO3	3	3	2			1						1	2	2
CO4	3	3	2			1						1	2	2
CO5	3	3	2			1						1	2	2
AVG	3	3	2			1						1	2	2

1: Slight (Low)      2: Moderate (Medium)      3: Substantial High      - : None

**X. QUESTION BANK (JNTUH)**

S. No	Question	Blooms Taxonomy Level	Course Outcome
<b>UNIT - I</b>			
<b>SHORT ANSWER TYPE QUESTIONS</b>			
1	List out the applications of HVDC?	Understand	1
2	What are the types of transmission system?	Analyze	1
3	State the comparison of AC & DC transmission system?	Remember	1

4	State the disadvantage in dc transmission?	Understand	1
5	State the advantages in DC transmission?	Remember	1
6	What are the types of DC link?	Understand	1
7	Name the HVDC transmission in india?	Understand	1
8	What are the limitations of EHVAC transmission?	Remember	1
9	What are the types of dc links?	Understand	1
10	Draw the cost vs distance curve of ac and dc transmission?	Understand	1
11	Define pulse number?	Remember	1
12	Draw the diagram graetz bridge circuit	Analyze	1
13	Write the equation of ac current and dc voltage harmonics	Analyze	1
14	What is choice of converter configuration?	Analyze	1
15	Define peak inverse voltage?	Remember	1
16	Draw the schematic diagram of three & two valve conduction mode	Understand	1
17	Define twelve pulse converter with schematic diagram	Remember	1
18	What is meant by neglecting overlap in gratez in bridge circuit	Remember	1
19	What is commutation voltage of valves?	Understand	1
20	What are the assumptions made to simplify the analysis of Gratez circuit?	Remember	1
<b>LONG ANSWER QUESTIONS</b>			
1	What are the different applications of dc transmission system? Explain them in detail?	Analyze	1
2	With neat sketches explain the different kinds of dc link available?	Analyze	1

3	Explain the comparison of AC and DC transmission in detail	Understand	1
4	Explain in detail about the planning of HVDC transmission?	Analyze	1
5	Explain the technological development of modern trends in dc transmission	Analyze	1
6	Explain the major components of HVDC transmission in converter station unit?	Apply	1
7	State the advantages and disadvantages of dc transmission system with following economics, reliability, and performance	Understand	1
8	Draw a typical HVDC layout and explain their basic components?	Analyze	1
9	Explain the modern trends in dc transmission?	Apply	1
10	Explain the application of HVDC c transmission system?	Analyze	1
11	Draw the schematic circuit diagram of a 6 pulse gratez circuit and explain its principle of operation.	Understand	1
12	Explain the individual characteristics of a rectifier and an inverter with sketch	Understand	1
13	Derive the expression for input power, output power and power factor of 12- pulse bridge converter with delay angle $\alpha$ . Assume there is no overlap.	Analyze	1
14	Explain the effect of overlap angle on the performance of converter circuit	Analyze	1
15	Explain the choice of converter configuration for any pulse number	Analyze	1
16	Explain the analysis of 12 pulse converter with bridge rectifier	Analyze	1

17	Give the typical converter transformer rating for a HVDC transmission system?	Analyze	1
18	Explain the term angle of advance and its significance in inverter control	Analyze	1
19	What are the different types of modes of operation of rectifier?	Understand	1
20	Write down the average dc voltage of Graetz circuit without overlap?	Understand	1
21	Compare EHVAC and HVDC transmission?	Understand	1
22	Explain the limitation of EHVAC system?	Understand	1
23	Explain the different types of HVDC link?	Understand	1
24	Explain the application of HVDC transmission system?	Understand	1
25	Explain the planning for HVDC transmission system?	Remember	1
26	Explain the modern trends in dc transmission?	Evaluate	1
27	Draw the variation of voltage along the transmission line during different loading condition?	Apply	1
28	What are the different applications of dc transmission system? Explain them in detail?	Apply	1
29	Explain in detail about the planning of HVDC Transmission?	Apply	1
30	State the advantages and disadvantages of dc transmission system with following economics, reliability, and performance	Apply	1
	Explain with the help of neat diagram and wave forms, the operation of 6-pulse bridge converter with delay angle $\alpha$ and overlap angle		

31	u. derive the expression for its dc output voltage	Remember	1
32	Show the rating of the valve used in gratez circuit is $2.094P_d$ where $P_d$ is dc power transmitted.	Understand	1
33	What are the different types of modes of operation of rectifier?	Remember	1
34	Write down the converter bridge characteristics?	Understand	1
35	Derive the expression for input power, output power and power factor of 6-pulse bridge converter with delay angle $\alpha$ . Assume there is no overlap.	Apply	1
36	Sketch the output dc voltage waveform and voltage across any one valve for 6- pulse bridge converter for the following two cases,  (i) Delay angle $\alpha=30$ degree and overlap angle $u=5$ degree.  (ii) angle of advance $\beta=30$ degree and overlap angle $u=5$ degree	Remember	1
37	Explain in detail the principle of DC Link control.	Apply	1
38	Explain firing angle control & current and extinction angle control	Remember	1
39	Sketch the output dc voltage waveform and voltage across any one valve for 12-pulse bridge	Apply	1
40	Give the typical converter transformer rating for aHVDC transmission system?	Apply	1

<b>UNIT - II</b>			
<b>SHORT ANSWER TYPE QUESTIONS</b>			
1	What will be the current regulation in inverter side?	Understand	2
2	Define firing angle control.	Understand	2
3	What is un compounded inverter?	Understand	2
4	Draw the characteristics curve for inverter compounding?	Analyze	2
5	Write down the converter bridge characteristics?	Analyze	2
6	Explain overlap angle and extinction angle.	Analyze	2
7	Discuss in detail the effect of source inductance on hvdc system	Analyze	2
8	Explain the individual characteristics of a rectifier and an inverter with sketches.	Analyze	2
9	Explain current and extinction angle control.	Analyze	2
10	Draw and explain the inverter and rectifier compounding characteristics with constant voltage and current curve.	Apply	2
<b>LONG ANSWER QUESTIONS</b>			
1	Explain firing angle control & current and extinction angle control	Analyze	2
2	Explain overlap angle and extinction angle.	Remember	2
3	Define the term angle of advance and its significance in inverter control	Remember	2
4	Explain the individual characteristics of a rectifier and an inverter with sketches	Analyze	2
5	Discuss in detail about the transformer tap changer with its types	Analyze	2
6	Discuss in detail about the converter control	Analyze	2

	characteristics of hvdc system		
7	Discuss in detail the principle of DC Link control.	Analyze	2
8	Explain the system control hierarchy	Analyze	2
9	Explain the un compounded inverter with neat sketches	Understand	2
10	Why the delay angle and extinction angles are to be maintained to minimum value	Understand	2
<b>ANALYTICAL QUESTIONS</b>			
1	Explain in detail the principle of DC Link control	Understand	2
2	Explain the term angle of advance and its significance in inverter control	Understand	2
3	What are the different types of modes of operation of rectifier?	Understand	2
4	Explain firing angle control & current and extinction angle control	Understand	2
5	Explain the system control hierarchy	Analyze	2
6	Explain overlap angle and extinction angle.	Apply	2
7	What will be the current regulation in inverter side	Apply	2
8	Why the delay angle and extinction angles are to be maintained to minimum value	Understand	2
9	Explain the individual characteristics of a rectifier and an inverter with sketches	Apply	2
10	Explain in detail about the transformer tap changer with its types	Apply	2

**UNIT - III**



### SHORT ANSWER TYPE QUESTIONS

1	Write the different types of AC/DC power flow	Analyze	3
2	What is unified method of DC power flow?	Understand	3
3	What is sequential method of DC power flow?	Remember	3
4	What are the advantages of variable elimination method over extended variable method?	Apply	3
5	Draw the DC system model	Remember	3
6	Draw the norton's equivalent circuit for a converter	Remember	3
7	What are the additional constraints needed to include for ac-dc power flow	Remember	3
8	List some essentials of power flow analysis	Evaluate	3
9	Compare sequential and simultaneous methods of ac-dc power flow.	Remember	3
10	What are the major steps in the power flow analysis of MTDC-AC Systems	Remember	3

### LONG ANSWER QUESTIONS

1	Discuss the various sources of reactive power for HVDC converters.	Understand	3
2	What is the reactive power requirement in steady state	Remember	3
3	Discuss conventional control strategies	Evaluate	3
4	Discuss alternate control strategies	Evaluate	3
5	Write the operation of synchronous condensers.	Analyze	3
6	Explain extended variable method of DC power flow	Analyze	3

7	Explain the variable elimination method of DC power flow	Evaluate	3
8	Explain the sequential method of DC power flow. Draw the necessary flow chart.	Evaluate	3
9	Explain about per unit system for DC quantities	Evaluate	3
10	Compare sequential and unified methods of DC power flow.	Apply	3

<b>UNIT - IV</b>			
<b>SHORT ANSWER TYPE QUESTIONS</b>			
1	What are the additional constraints needed to include for ac-dc power flow?	Remember	4
2	List some essentials of power flow analysis	Evaluate	4
3	Compare sequential and simultaneous methods of ac-dc power flow.	Remember	4
4	What are the major steps in the power flow analysis of MTDC-AC Systems	Remember	4
5	Define AC filter?	Remember	4
6	Define DC Filter?	Understand	4
7	What are the components present in AC & DC filter?	Remember	4
8	What are the types of AC filters & Dc?	Apply	4
9	Define single tuned filter?	Remember	4
10	How will protect the filter?	Remember	4

**LONG ANSWER QUESTIONS**

1	Discuss the various sources of active power for HVDC converters	Understand	4
2	What is the reactive power requirement in	Apply	4

	steady state		
3	Explain extended variable method of DC power flow	Remember	4
4	Explain the variable elimination method of DC power flow	Remember	4
5	Explain the sequential method of DC power flow. Draw the necessary flow chart	Remember	4
6	Explain about per unit system for DC quantities	Remember	4
7	Compare sequential and unified methods of DC power flow	Apply	4
8	Explain unified method of DC power flow	Remember	4
9	What are the additional constraints needed to include for ac-dc power flow?	Understand	4
10	Compare sequential and simultaneous methods of ac-dc power flow	Apply	4
11	State the various sources of harmonics generation in HVDC-VSC systems and mention the adverse effects caused by these harmonics	Apply	4
12	With neat sketches, explain how a converter transformer is responsible for generation of harmonics and suggest various methods for minimising them	Evaluate	4
13	Define telephone interference Factor and Explain how it varies with harmonic order.	Remember	4
14	What are the non-characteristics of harmonics in HVDC system? How are they generated?	Evaluate	4
15	What are other methods of eliminating harmonics with HVDC system	Apply	4

16	Explain the need to employ filter circuit in HVDC systems. Derive an Expression for minimum cost of tuned AC filters used in HVDC systems.	Apply	4 4
17	Derive an equation for harmonic voltage and current for single tuned filter and discuss the influence of network admittance	Analyse	4
18	Give a detailed account of design aspects of following filters (a) Single tuned filter (b) Double tuned filter	Analyse	4 4
19	What are the other methods of eliminating or suppressing harmonics with HVDC system? Give a comparison using passive filter network	Analyse	4

<b>UNIT - V</b>			
<b>SHORT ANSWER TYPE QUESTIONS</b>			
1	Define Harmonic	Analyse	5
2	How harmonics are generated?	Understand	5
3	Mention the various sources of harmonic generation in HVDC system	Remember	5
4	What are other methods of eliminating harmonics with HVDC system	Remember	5
5	Write the different types of AC/DC power flow	Analyse	5
6	What is unified method of DC power flow?	Understand	5
7	What is sequential method of DC power flow?	Remember	5
8	What are the advantages of variable elimination method over extended variable method?	Apply	5
9	Draw the DC system model	Remember	5

10	Draw the norton's equivalent circuit for a converter	Understand	5
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**LONG ANSWER QUESTIONS**

1	Explain unified method of DC power flow	Analyze	5
2	What are the additional constraints needed to include for ac-dc power flow?	Analyze	5
3	Compare sequential and simultaneous methods of ac-dc power flow	Apply	5
4	Write a short note on the following: (a) Harmonic distortion (b) telephone Influence factor	Apply	5 5 5
5	Mention the various sources of harmonic generation in HVDC systems and suggest methods to eliminate them	Analyze	5
6	Define telephone interference Factor and Explain how it varies with harmonic order.	Analyze	5
7	What are the order of harmonics present on the AC side of the VSC converter DC systems	Analyze	5
8	What are the filter configurations that are employed for HVDC Converter station? Give design aspect of one such filter	Understand	5
9	Derive an equation for harmonic voltage and current for single tuned filter and discuss the influence of network admittance	Evaluate	5
10	Give a detailed account of design aspects of following filters (a) Single tuned filter (b) Double tuned filter	Understand	5 5 5
11	What are the different types of filters used on the AC side of an HVDC system? How are they located and arranged?	Apply	5

**OBJECTIVE QUESTIONS:**

**UNIT-1**

1) Which among these HVDC projects are commissioned in India?

- a. Rihand – Delhi HVDC
- b. Vindhyachal Back to Back only
- c. Chandrapur only
- d. All of these
- e. None of these

ans:d

2) At what location are the shunt capacitors installed for voltages above 33 kV and above?

- a. Are located near the motors
- b. Are installed in distribution substations
- c. Both (A) and (B)
- d. None of these

ans:b

3) What is meant by Creepage Distance?

- a. Shortest distance between two conducting parts along a stretched string.
- b. Shortest distance between two conducting parts along the surface of the insulating material.
- c. Distance between ground and the highest earthed point on the equipment.
- d. All of these

ans:b

4) Which among these is a part of HVDC link?

- a. Two earth electrodes
- b. Converter valves

- c. Bipolar DC line
- d. All of these
- e. None of these

ans:d

5) At what level is the load shedding carried out?

- a. Distribution level
- b. Transmission level
- c. Both (A) and (B)
- d. Depending upon the load

ans:a

## UNIT-2

1) Which place is the 'Regional load dispatch centre' for the western region in the national grid?

- a. Mumbai
- b. Ahmadabad
- c. Bhopal
- d. Nagpur

ans:a

2) What type of insulation is preferred for DC smoothing Reactors?

- a. Air
- b. Oil
- c. Paper
- d. Varnish

ans:b

3) At what condition does the corona start, if  $E_s$  is the electrical stress and  $E_{cr}$  is the critical voltage?

- a.  $E_s > E_{cr}$
- b.  $E_s = E_{cr}$
- c.  $E_s < E_{cr}$
- d.  $E_s \ll E_{cr}$

ans:a

4) Which method of voltage control is applied for long line AC transmissions?

- a. Switching by shunt capacitors
- b. Tap changing transformers
- c. Switching by shunt reactors
- d. Static Var sources

ans: c

5) For what voltage is Twin conductor bundle used in India?

- a. 220 kV
- b. 500 kV
- c. 750 kV
- d. 330 kV

ans:b

### UNIT 3

1. Which type of dc link, all conductors have negative polarity

- (a) Homopolar (b) Monopolar (c) Bipolar (d) None

ans:a

2. When two power systems are connected through ac ties, the automatic generation control of both systems have to be coordinated using

- (a) Line current & voltage signals (b) Line power & voltage signals  
(c) Line power & frequency signals (d) Line current & frequency signals

ans :c

3. Which factor must be considered by system planner for expansion of dc alternative in transmission

- (a) Cost (b) Technical performance (c) Reliability (d) All



**ans:d**

4. The break even distance can vary in the range for over head lines

- (a)300km      (b)500km      (c) 100km      (d) 1000km

**ans:b**

5. The following is the application of hvdc transmission (a)Small distance bulk power transmission (b) Medium bulk power transmission

- (c)Long distance bulkpower transmission      (d)None

**ans:c**

#### **UNIT 4**

1. HVDC transmission commercially began in the year

- (a)1950      (b) 1954      (c) 1970      (d)1935

**ans:b**

2. Modern HVDC systems are all

- (a) 3-pulse converters      (b) 6-pulse converters  
(c) 24-pulse converters      (d) 12-pulse converters

**ans:b**

3. The break even distance is the distance beyond which

- (a) DC transmission is economical      (b) AC transmission is economical  
(c) Cost of the both systems are same      (d) Both(b)and(c)

**ans:a**

4. The initial HVDC valves were

- (a) IGATS      (b) Thyristors  
(c) Mercury arc valves      (d) None of the above

ans:c

5. Thyristor valves came into operation in the year

(a)1950 (b)1954 (c)1972 (d)2000

ans :b

## UNIT-5

### Fill in the blanks

1. The synchronous condenser which is operated at \_\_\_\_\_

2. The first HVDC scheme in India \_\_\_\_\_

3. HVDC-VSC scheme employs in \_\_\_\_\_

4. In 12-pulse converter transformers are connected-----

5. The main advantage of HVDC over HVAC \_\_\_\_\_

**Answers:** 1. Lagging power factor 2. Delhi-Rihand 500kv system 3. Light or optically triggered 4. one Star/Star and other Star/Delta 5. Transmission loss less

### XI. WEBSITES:

[https://www.edx.org/course/HVDC transmission](https://www.edx.org/course/HVDC%20transmission)

[https://www.edx.org/micromasters/EHV vs HVDC](https://www.edx.org/micromasters/EHV%20vs%20HVDC)

### XII. EXPERT DETAILS: NA

### XIII. JOURNALS:

#### INTERNATIONAL

1. International Journal of smart grid transmission (IJS GT)
2. International Journal of Power system transmission (IJPST)

## **NATIONAL**

1. Journal of power system and Applications
2. Journal of energy Research and Development

### **XIV. LIST OF TOPICS FOR STUDENT SEMINARS:**

1. Advanced dc link protections
2. Comparison between EHV and UHV
3. HVDC control and operations.

### **XV. CASE STUDIES / SMALL PROJECTS:**

1. Preparing layout for HVDC transmission station
2. Develop the step by step procedure for the HVDC transmission.

**==== END ====**