Techno India NJR Institute of Technology

Course File

HVDC Transmission System (8EE4-11)

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Department of Electrical Engineering

Syllabus:

RAJASTHAN TECHNICAL UNIVERSITY, KOTA

Scheme & Syllabus

IV Year- VII & VIII Semester: B. Tech. (Electrical Engineering)

8EE4-11: HVDC TRANSMISSION SYSTEM

Credit: 3 **Max. Marks: 150(IA:30, ETE:120)**

3L+0T+0P **End Term Exam: 3 Hours**

SN	CONTENTS	Hours
1	**Introduction:** Objective, scope and outcome of the course.	01
2	**dc Transmission Technology:** Comparison of AC and dc Transmission (Economics, Technical Performance and Reliability). Application of DC Transmission. Types of HVdc Systems. Components of a HVdc system. Line Commutated Converter and Voltage Source Converter based systems.	04
3	**Analysis of Line Commutated and Voltage Source Converters:** Line Commutated Converters (LCCs): Six pulse converter, Analysis neglecting commutation overlap, harmonics, Twelve Pulse Converters. Inverter Operation. Effect of Commutation Overlap. Expressions for average dc voltage, AC current and reactive power absorbed by the converters. Effect of Commutation Failure, Misfire and Current Extinction in LCC links. Voltage Source Converters (VSCs): Two and Three-level VSCs. PWM schemes: Selective Harmonic Elimination, Sinusoidal Pulse Width Modulation. Analysis of a six pulse converter. Equations in the rotating frame. Real and Reactive power control using a VSC.	10
4	**Control of HVdc Converters:** Principles of Link Control in a LCCHVdc system. Control Hierarchy, Firing Angle Controls – Phase-Locked Loop, Current and Extinction Angle Control, Starting and Stopping of a Link. Higher level Controllers Power control, Frequency Control, Stability Controllers. Reactive Power Control. Principles of Link Control in a VSC HVdc system: Power flow and dc Voltage Control. Reactive Power Control/AC voltage regulation	10
5	**Components of HVdc systems:** Smoothing Reactors, Reactive Power Sources and Filters in LCC HVdc systems DC line: Corona Effects. Insulators, Transient Over-voltages. dc line faults in LCC systems. dc line faults in VSC systems. dc breakers. Monopolar Operation. Ground Electrodes	08
6	**Stability Enhancement using HVdc Control:** Basic Concepts: Power System Angular, Voltage and Frequency Stability. Power Modulation: basic principles – synchronous and asynchronous links. Voltage Stability Problem in AC/dc systems.	04
7	**MTdc Links:** Multi-Terminal and Multi-Infeed Systems. Series and Parallel MTdc systems using LCCs. MTdc systems using VSCs. Modern Trends in HVdcTechnology. Introduction to Modular Multi-level Converters	04
	TOTAL	

Course Overview:

This course aims to develop the skills in the area of HVDC power transmission system with the analysis of HVDC converters, harmonics and design of filters in this 41-hour course. The first part starts with an introduction to why HVDC is increasingly applied in power systems. HVDC LCC technology and its main applications are explained, including the controls and associated DC and AC equipment. In the second part, the substation part is followed by VSC technology with a control system module for VSC and associated AC and equipment specification, including commissioning and failure investigations. AC/DC load flow and stability analysis, multi-terminal HVDC, different application of HVDC system, advances in HVDC systems are discussed.

This course is very important for the student to get into power conversion industry. This will develop problem solving capability along with the designing solution. This course is the core of power handling and power system stability improvement.

Course Outcome:

CO. NO.	Cognitive Level	Course Outcome
1	Synthesis	Student will be able to explain HVDC transmission and HVDC converters and the applicability and construct the advantage of HVDC transmission over conventional AC transmission.
2	Synthesis	Student will be able to formulate and solve mathematical problems related to rectifier and inverter control methods and learn about different control schemes as well as starting and stopping of DC links
3	Analysis	Students will be able to analyze the different harmonics generated by the converters and their variation with the change in firing angles.
4	Synthesis	Students will be able to develop harmonic models and use the knowledge of circuit theory to design filters and assess the requirement and type of protection for the filters.
5	Application	Student will be able to apply and identify the nature of faults happening on both the AC and DC sides of the converters and prepare protection schemes for the same

Prerequisites:

1. Basic Electrical Engineering, Circuit theory, Power Electronics
2. Fundamentals of Power System Analysis and filter design.
3. Students should be proficient in solving mathematical equations.

Course Outcome Mapping with Program Outcome:

Course Outcome	Program Outcomes (PO's)											
CO. NO.	Domain Specific (PSO)					Domain Independent (PO)						
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO11	PO11	PO12
CO1	3	2	1	1	-	-	1	-	-	1	-	1
CO2	2	2	2	1	-	-	1	-	-	-	-	1
CO3	2	2	1	1	-	-	-	-	-	-	-	-
CO4	2	2	1	-	1	-	-	-	-	-	-	-
CO5	2	2	2	1	2	-	-	-	-	-	-	-
1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High)												

Course Coverage Module Wise:

Lect. No.	Unit	Topic
1	**1**	**Introduction:** Objective, scope and outcome of the course. 01
2	**2**	**Dc Transmission Technology:** Comparison of AC and dc Transmission
3	2	(Economics, Technical Performance and Reliability). Application of DC
4	2	Transmission. Types of HVdc Systems. Components of a HVdc system.
5	2	Line Commutated Converter and Voltage Source Converter based systems.
6	**3**	**Analysis of Line Commutated and Voltage Source Converters: Line**
7	3	Commutated Converters (LCCs): Six pulse converter, Analysis neglecting
8	3	commutation overlap, harmonics, Twelve Pulse Converters. Inverter
9	3	Operation. Effect of Commutation Overlap. Expressions for average dc
10	3	voltage, AC current and reactive power absorbed by the converters.
11	3	Effect of Commutation Failure, Misfire and Current Extinction in LCC links.
12	3	Voltage Source Converters (VSCs): Two and Three-level VSCs. PWM
13	3	schemes: Selective Harmonic Elimination, Sinusoidal Pulse Width
14	3	Modulation. Analysis of a six pulse converter. Equations in the rotating
15	3	frame. Real and Reactive power control using a VSC.
16	**4**	**Control of HVDC Converters:**
17	4	Principles of Link Control in a LCCHVdc

18	4	Control Hierarchy,
19	4	Firing Angle Controls – Phase-Locked Loop,
20	4	Current and Extinction Angle Control, Starting and Stopping of a Link.
21	4	Higher level Controllers Power control, Frequency Control, Stability
22	4	Controllers. Reactive Power Control.
23	4	Principles of Link Control in a VSC
24	4	HVDC system: Power flow and dc Voltage Control. Reactive Power Control/
25	4	AC voltage regulation
26	**5**	**Components of HVdc systems:**
27	5	Smoothing Reactors, Reactive Power
28	5	Sources and Filters in LCC HVdc systems DC line:
29	5	Corona Effects. Insulators,
30	5	Transient Over-voltages. dc line faults in LCC systems. dc line
31	5	Faults in VSC systems. dc breakers. Monopolar Operation.
32	5	Ground Electrodes
33	**5**	Stability Enhancement using HVdc Control: Basic Concepts: Power
34	**6**	**System Angular, Voltage and Frequency Stability. Power**
35	6	Modulation: basic principles – synchronous and asynchronous links.
36	6	Voltage Stability Problem in AC/dc systems.
37	6	MTDC Links: Multi-Terminal and Multi-Infeed Systems. Series and Parallel
38	**7**	**MTDC systems using LCCs.**
39	7	MTDC systems using VSCs.
40	7	Modern Trends in HVDC Technology.
41	7	Introduction to Modular Multi-level Converters

Text/Reference Books:

1. K. R. Padiyar, “HVDC Power Transmission Systems”, New Age International Publishers, 2011.
2. J. Arrillaga, “High Voltage Direct Current Transmission”, Peter Peregrinus Ltd., 1983.
3. E. W. Kimbark, “Direct Current Transmission”, Vol.1, Wiley-Interscience, 1971.

Teaching and Learning resources:

NPTEL Course Link	https://nptel.ac.in/courses/108/104/108104013/
Quiz	https://quizizz.com/admin/quiz/5fa25913a2a0d8001b6f72ed/hvdc
Notes	https://sites.google.com/site/eeenotes2u/courses/hvdc-notes

Assessment Methodology:

1. Assignments one from each unit.
2. Midterm subjective paper where they have to solve the given problem. (Twice during the semester)
3. Final paper at the end of the semester subjective.

For Techno India NJR Institute of Technology
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Dr. Pankaj Kumar Porwal
(Principal)