GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering (Part Time)
Subject Code: 2950907
Semester – 5
Subject Name: HVDC Transmission Systems

Type of course: Professional Elective Course

Prerequisite: Electrical Power system I and II. The knowledge of Power Electronics I and II is additionally required.

Rationale: This subject is offered at higher UG level to study the various operating as well as configurational aspects of HVDC transmission system. The control strategy for frequency and voltage regulation in DC link is covered in detail for interconnected HVDC system. It also presents the power system stability and fault analysis. Students will be able to enhance their learning domain by distinguishing the requirement of HVDC system over HVAC system. They will also learn the components used and role of power electronics involved for regulating the voltage angle and frequency for power flow and interconnection.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Content:

Sr. No.	Content	Total Hrs
1	**HVDC Transmission: The State of Art** Introduction, Historical Developments, Comparison of AC and DC Transmission (Economics, Technical Performance and Reliability). Application of DC Transmission, Types of HVDC Systems, Limitations of HVDC Transmission lines, Components of a HVDC system, Line Commutated Converter and Voltage Source Converter based HVDC Systems.	06
2	**Analysis of Line Commutated Converters** Line Commutated Converters (LCCs): Basic Principal of three-phase AC–DC Conversion, six pulse converter operation, Effect of Delaying the Firing Instant, The Commutation Process, Analysis of the Commutation Circuit, Analysis neglecting commutation overlap, Rectifier Operation, Inverter Operation, Power Factor and Reactive Power, Characteristic Harmonics, DC Side Harmonics, AC Side Harmonics, Twelve Pulse Converters operation, AC/DC side voltage and current waveforms, Expressions for average dc voltage.	08

Suggested Specification table with Marks (Theory): (For BE only)

3	**Voltage Source Converters (VSCs)** VSC Operating Principle, PWM schemes: Selective Harmonic Elimination, Sinusoidal Pulse Width Modulation, PWM Carrier-Based Implementation, Naturally Sampled PWM, Uniformly Sampled PWM, Equation in rotating reference frame, Real and Reactive power control using a VSC.	**04**
4	**Control of HVDC Converters and System** Principles of DC Link Control in a LCC HVDC System. Control Hierarchy, Firing Angle Control, Phase-Locked Loop, Current and Extinction Angle Control, Starting and Stopping of a DC Link. Higher level Controllers, Power control, Frequency Control, Reactive Power Control, Principles of DC Link Control in a VSC based HVDC system: Power flow and dc voltage control. Reactive Power Control / AC voltage regulation using VSC.	**10**
5	**Components of HVDC Systems** Smoothing Reactors, Reactive Power Sources and Filters in LCC HVDC systems DC line: Corona Effects, Insulators and Transient Over-voltages. DC line faults in LCC systems. DC line faults in VSC systems, dc breakers, Mono-polar 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	**Multi Terminal HVDC System** Introduction, Types of Multi-terminal HVDC System, Parallel Operation of HVDC, Control of Power in MTDC, Disconnecting of units or converters, Modern Trends in HVDC Technology. Introduction to Modular Multi-level Converters.	**04**

Distribution of Theory Marks

R Level	U Level	A Level	N Level	E Level	C Level
15	**30**	**20**	**25**	**10**	**0**

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

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- Inder-science, 1971.
4. Vijay K Sood, "HVDC and FACTS Controller" Springer Publication, 2004.
5. S Kamakshaiah and V Kamaraju, "HVDC Transmission" TMH Publications, 2011.
6. M. H Rashid, "Power Electronics Handbook" Academic Press, 2001.

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Course Outcomes:

At the end of this course, students will have the ability to

Sr. No.	CO statement	Marks % weightage
CO-1	Understand the advantages of dc transmission over ac transmission.	**10**
CO-2	Analysis of Line Commutated Converters and Voltage Source Converters in HVDC Transmission System.	**35**
CO-3	Application of suitable control strategies used for LCC and VSC based HVDC transmission system.	**25**
CO-4	Evaluation of Power system angular, voltage and frequency stability using simulation models for various configuration of an HVDC system.	**30**

List of Experiments: Suggested List (But not the least)

1. Study of various HVDC transmission system components and its applications.
2. Study of AC/DC side voltage and current waveforms of six pulse converter system under variable R-L Load using simulation. (Hint: input PF, THD, converter efficiency, reactive power flow etc).
3. Study of AC/DC side voltage and current waveforms of twelve pulse converter system under variable R-L Load using simulation. (Hint: input PF, THD, converter efficiency, reactive power flow etc).
4. Study of reactive power control in HVDC transmission system.
5. Study of various types of Multi terminal HVDC transmission system.
6. Some simulation practices based on HVDC power and voltage stability.
7. Study of DC link control in VSC based HVDC transmission system.
8. Study of various passive filters used in LCC based HVDC transmission system.
9. Operation of VSC for power factor correction at AC side of HVDC system using sinusoidal pulse width modulation.

The above practical list is based on model syllabus. However, Hands-on MATLAB simulation based models related to the course contents can be carried out. It can include modeling of power electronics based switching devices used for rectification and inversion procedure in HVDC transmission system. The coupling of two asynchronous systems can also be modeled for power flow and frequency control analysis.

Note**: Visit to HVDC Transmission Substation is encouraged near Chandrapur–Padghe, Maharastra.

Major Equipment: Not Applicable

List of Open Source Software/learning website:

https://nptel.ac.in