INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)
Dundigal, Hyderabad-500043

ELECTRICAL AND ELECTRONICS ENGINEERING

TUTORIAL QUESTION BANK

Course Title	**HVDC TRANSMISSION**				
Course Code	**BPSB03**				
Programme	M.Tech				
Semester	I	EPS			
Course Type	Elective				
Regulation	**IARE - R18**				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	-	3	-	-
Chief Coordinator	Dr. P Sridhar, Professor, HOD, EEE				
Course Faculty	Dr. P Sridhar, Professor, HOD, EEE				

COURSE OBJECTIVES:

The course should enable the students to:	
I	Understand state of the art HVDC technology
II	Learn the methods to carry out modelling and analysis of HVDC system frontier- area power flow regulation

COURSE OUTCOMES (COs):

CO 1	Classify AC and DC transmission and understand control characteristics of HVDC system.
CO 2	Explain the working of HVDC converter in rectifier and inverter modes of operation.
CO 3	Understand different control schemes used in HVDC converters
CO 4	Understand the nature of faults happening on both the AC and DC sides of the converters and formulate protection schemes for the same.
CO 5	Develop harmonic models and use the knowledge of circuit theory to develop filters and assess the requirement and type of protection for the filters.

COURSE LEARNING OUTCOMES (CLOs):

BPSB03.01	Illustrate the layout of HVDC converter stations.
BPSB03.02	Understand the difference between HVDC and HVAC transmission
BPSB03.03	Describe the converter control characteristics of HVDC systems.
BPSB03.04	Analyze single phase and three phase converters and understand its properties
BPSB03.05	Demonstrate the rectifier configurations of 12 pulse HVDC converter.
BPSB03.06	Understand the working of inverter configuration of HVDC converter.
BPSB03.07	Understand different modes of operation of converters.
BPSB03.08	Analyze the output waveforms for rectifier and inverter circuits
BPSB03.09	Examine the control schemes for HVDC transmission systems.
BPSB03.10	Analyze the characteristics of HVDC converter with respect to Constant current and Constant voltage
BPSB03.11	Understand actual and desired characteristics of a converter
BPSB03.12	Understand the concept of power reversal in HVDC converters
BPSB03.13	Illustrate the starting and stopping of converter bridge
BPSB03.14	Analyze various aspects responsible for commutation failure
BPSB03.15	Analyze the adverse effects of HVDC converter on equipment
BPSB03.16	Understand different methods used in protection of HVDC converter
BPSB03.17	Understand controllers for controlling the power flow through a dc link
BPSB03.18	Analyze the Harmonics and use of filters to minimize the harmonics.
BPSB03.19	Understand the importance of smoothening reactors in HVDC converters
BPSB03.20	Analyze the harmonics and basis of protection for HVDC System.

TUTORIAL QUESTION BANK

UNIT-I

GENERAL ASPECTS OF HVDC TRANSMISSION

Part - A (Short Answer Questions)

S No	QUESTIONS	Blooms Taxonomy Level	Course Outcomes	Course Learning Outcomes (CLOs)
1	List out the applications of HVDC?	Remember	CO 1	BPSB03.03
2	What are the types of transmission system?	Remember	CO 1	BPSB03.02
3	State the comparison of AC & DC transmission system?	Remember	CO 1	BPSB03.02
4	What are the disadvantages in DC transmission?	Understand	CO 1	BPSB03.02
5	State the economic advantages in DC transmission?	Understand	CO 1	BPSB03.02
6	What are the types of DC link?	Remember	CO 1	BPSB03.02
7	What are the limitations of EHVAC transmission?	Remember	CO 1	BPSB03.02
8	What are the types of dc links?	Remember	CO 1	BPSB03.04
9	Draw the cost vs distance curve of ac and dc transmission?	Remember	CO 1	BPSB03.02
10	Define pulse number?	Remember	CO 1	BPSB03.01
11	Write the equation of ac current and dc voltage harmonics	Understand	CO 1	BPSB03.01
12	What is choice of converter configuration?	Understand	CO 1	BPSB03.01
13	Define peak inverse voltage?	Understand	CO 1	BPSB03.01
14	Draw the schematic diagram of three & two valve conduction mode	Understand	CO 1	BPSB03.04
15	What is commutation voltage of valves?	Understand	CO 1	BPSB03.04
16	Compare EHVAC and HVDC transmission?	Remember	CO 1	BPSB03.02
17	What are the limitations of EHVAC system?	Remember	CO 1	BPSB03.02
18	What are the different types of HVDC link?	Remember	CO 1	BPSB03.02
19	List out the application of HVDC transmission system?	Understand	CO 1	BPSB03.02
20	Explain the modern trends in dc transmission?	Understand	CO 1	BPSB03.01

Part - B (Long Answer Questions)				
1	What are the different applications of dc transmission system? Explain them in detail?	Remember	CO 1	BPSB03.02
2	With neat sketches explain the different kinds of dc link available?	Understand	CO 1	BPSB03.02
3	Explain the comparison of AC and DC transmission in detail	Understand	CO 1	BPSB03.02
4	Explain in detail about the planning of HVDC transmission?	Understand	CO 1	BPSB03.01
5	Explain the technological development of modern trends in dc transmission	Remember	CO 1	BPSB03.01
6.	Explain the major components of HVDC transmission in converter station unit?	Remember	CO 1	BPSB03.01
7.	State the advantages and disadvantages of dc transmission system with following economics, reliability, and performance	Remember	CO 1	BPSB03.02
8	Draw a typical HVDC layout and explain their basic components?	Remember	CO 1	BPSB03.01
9.	Explain the modern trends in dc transmission?	Remember	CO 1	BPSB03.01
10	Explain the application of HVDC c transmission system?	Understand	CO 1	BPSB03.01
11	Draw the variation of voltage along the transmission line during different loading condition?	Understand	CO 1	BPSB03.04
12	What are the different applications of dc transmission system? Explain them in detail?	Understand	CO 1	BPSB03.04
13	Explain in detail about the planning of HVDC Transmission?	Understand	CO 1	BPSB03.01
14	Give the typical converter transformer rating for a HVDC transmission system?	Understand	CO 1	BPSB03.03
15	Explain in detail the principle of DC Link control. With a neat sketch explain different types of DC link control	Remember	CO 1	BPSB03.04
16	With the help of a neat schematic diagram of a typical HVDC converter station explain the functions of various components available.	Understand	CO 1	BPSB03.01
17	It is required to eliminate harmonics of order 10 and below 10 other than fundamental in a 12 pulse converter. Suggest a suitable transformer configuration and derive an equation for primary current of transformer.	Understand	CO 1	BPSB03.03
18	Compare the HVDC transmission and HVAC transmission with reference to following factors a. Economics b. Technical performance c. Reliability	Understand	CO 1	BPSB03.01
19	Enumerate the relative merits and demerits of constant current control and constant voltage control of HVDC link.	Remember	CO 1	BPSB03.03
20	Explain the process of starting and stopping of DC link in HVDC system.	Remember	CO 1	BPSB03.03
UNIT- II				
ANALYSIS OF BRIDGE CONVERTER				
Part-A (Short Answer Questions)				
1	Draw the diagram Graetz bridge circuit.	Remember	CO 2	BPSB03.05
2	Why modern HVDC system uses 12 pulses?	Remember	CO 2	BPSB03.05
3	What is the turn-off time for converter grade SCRs and inverter grade SCRs?	Remember	CO 2	BPSB03.06
4	What is meant by pulse number of a converter?	Remember	CO 2	BPSB03.05
5	Write the assumptions for analysis of 6 pulse converter	Understand	CO 2	BPSB03.05
6	Define twelve pulse converters with schematic diagram	Remember	CO 2	BPSB03.05
7	What is meant by neglecting overlap in Gratez in bridge circuit	Understand	CO 2	BPSB03.05
8	List the assumptions made to develop the equivalent circuit of converter	Understand	CO 2	BPSB03.05
9	What are the assumptions made to simplify the analysis of Gratez circuit?	Remember	CO 2	BPSB03.05
10	Mention the various modes of operation of rectifier characteristics.	Understand	CO 2	BPSB03.08
11	Mention the various modes of operation of inverter characteristics.	Remember	CO 2	BPSB03.06
12	Draw the diagram of 12 pulse converter circuit.	Remember	CO 2	BPSB03.05
13	Why series and parallel operation of thyristor in HVDC transmission?	Remember	CO 2	BPSB03.05
14	List at least four projects on HVDC in India.	Understand	CO 2	BPSB03.05
15	Define break even distance- give its range of value for overhead line	Understand	CO 2	BPSB03.05

16	What are the characteristics of bridge converter	Understand	CO 2	BPSB03.05
17	Mention the some of HVDC projects from abroad?	Remember	CO 2	BPSB03.05
18	What are the demerits of solid-state bridge in HVDC system?	Understand	CO 2	BPSB03.05
19	What are the merits of mercury arc bridge?	Understand	CO 2	BPSB03.05
20	List out the applications of HVDC transmission system.	Remember	CO 2	BPSB03.07
	Part-B (Long Answer Questions)			
1	Draw the schematic circuit diagram of a 6 pulse Gratez circuit and explain its principle of operation.	Remember	CO 2	BPSB03.05
2	Explain the individual characteristics of a rectifier and an inverter with sketch	Understand	CO 2	BPSB03.08
3	Derive the expression for input power, output power and power factor of 12-pulse bridge converter with delay angle α. Assume there is no overlap.	Understand	CO 2	BPSB03.05
4	Explain the effect of overlap angle on the performance of converter circuit	Understand	CO 2	BPSB03.05
5	Explain the choice of converter configuration for any pulse number	Remember	CO 2	BPSB03.05
6	Explain the analysis of 12 pulse converter with bridge rectifier	Understand	CO 2	BPSB03.05
7	Explain the term angle of advance and its significance in inverter control	Understand	CO 2	BPSB03.08
8	What are the different types of modes of operation of rectifier?	Understand	CO 2	BPSB03.08
9	Write down the average dc voltage of Graetz circuit without overlap?	Understand	CO 2	BPSB03.05
10	Sketch the output dc voltage waveform and voltage across any one valve for 12-pulse bridge	Understand	CO 2	BPSB03.05
11	Show the rating of the valve used in Gratez circuit is 2.094Pd where Pd is dc power transmitted.	Understand	CO 2	BPSB03.05
12	What are the different types of modes of operation of rectifier?	Understand	CO 2	BPSB03.08
13	Write down the converter bridge characteristics?	Understand	CO 2	BPSB03.05
14	Explain with the help of neat diagram and wave forms, the operation of 6-pulse bridge converter with delay angle a and overlap angle u. derive the expression for its dc output voltage	Understand	CO 2	BPSB03.05
15	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 α=30 degree and overlap angle u=5 degree. (ii) angle of advance β=30 degree and overlap angle u=5 degree	Understand	CO 2	BPSB03.05
16	Derive the expression for input power, output power and power factor of 6-pulse bridge converter with delay angle α. Assume there is no overlap.	Understand	CO 2	BPSB03.05
17	Derive V-I characteristics of an inverter operating with constant advance angle. Show these characteristics in VI plane	Understand	CO 2	BPSB03.08
18	Detail the areas of HVDC-transmission. Also discuss various types of D.C.Links and show clearly how is one type different from other types	Understand	CO 2	BPSB03.04
19	Discuss analysis of 3-phase (six-pulse)-converter with grid control overlap angle, u < 60°.	Understand	CO 2	BPSB03.05
20	Derive the expression for DC voltage and voltage drop due to overlap and hence deduce the equivalent circuit of bridge rectifier	Understand	CO 2	BPSB03.08
	UNIT III			
	HVDC CONTROL TECHNIQUES			
	Part-A(Short Answer Questions)			
1	Explain briefly about Grid control?	Understand	CO 3	BPSB03.09
2	List out the desired features in DC transmission line	Understand	CO 3	BPSB03.11
3	Draw combined characteristics of HVDC converter.	Understand	CO 3	BPSB03.10
4	What are functions of converter unit control and value unit control of HVDC transmission system?	Understand	CO 3	BPSB03.10
5	Write a short note on constant alpha control.	Understand	CO 3	BPSB03.10
6	Write a short note on inverse cosine control.	Understand	CO 3	BPSB03.10
7	List advantages of individual phase control.	Understand	CO 3	BPSB03.10
8	Discuss drawbacks of equidistant phase control over individual phase control.	Understand	CO 3	BPSB03.10
9	Write a short note on starting of DC link.	Understand	CO 3	BPSB03.09

10	List out the disadvantages of manual control.	Understand	CO 3	BPSB03.10
11	What will be the current regulation in inverter side?	Understand	CO 3	BPSB03.10
12	Define firing angle control.	Understand	CO 3	BPSB03.10
13	What is un compounded inverter?	Understand	CO 3	BPSB03.10
14	Draw the characteristics curve for inverter compounding?	Understand	CO 3	BPSB03.10
15	Write down the converter bridge characteristics?	Understand	CO 3	BPSB03.10
16	Explain overlap angle and extinction angle.	Remember	CO 3	BPSB03.10
17	Discuss in detail the effect of source inductance on HVDC system.	Remember	CO 3	BPSB03.09
18	Explain the individual characteristics of a rectifier and an inverter with sketches.	Remember	CO 3	BPSB03.09
19	Explain current and extinction angle control.	Remember	CO 3	BPSB03.10
20	Draw and explain the inverter and rectifier compounding characteristics with constant voltage and current curve.	Remember	CO 3	BPSB03.10
	Part–B(LongAnswerQuestions)			
1	Discuss in detail the principle of DC Link control.	Understand	CO 3	BPSB03.09
2	Explain briefly the hierarchical level of control of HVDC transmission system.	Understand	CO 3	BPSB03.09
3	What are the desired features of control? Why and explain?	Understand	CO 3	BPSB03.11
4	Compare constant voltage and constant current control of HVDC converters	Remember	CO 3	BPSB03.10
5	What are the limitations of manual control of DC line operation	Understand	CO 3	BPSB03.10
6	From fundamentals, deduce the basic equation of control. Also draw the equivalent circuit diagram of HVDC converter used for analyzing control concept	Understand	CO 3	BPSB03.09
7	With steady state equivalent circuit, explain the principle of control of two terminal DC link.	Understand	CO 3	BPSB03.09
8	Distinguish between constant voltage and constant current control.	Understand	CO 3	BPSB03.10
9	With a block diagram explain the hierarchical control structure for a DC link	Understand	CO 3	BPSB03.09
10	What are the basic characteristics of converter control? with the aid of V-I characteristics explain the power flow control.	Understand	CO 3	BPSB03.09
11	Explain firing angle control & current and extinction angle control	Understand	CO 3	BPSB03.10
12	Explain overlap angle and extinction angle.	Understand	CO 3	BPSB03.10
13	Define the term angle of advance and its significance in inverter control	Understand	CO 3	BPSB03.11
14	Explain the individual characteristics of a rectifier and an inverter with sketches	Understand	CO 3	BPSB03.10
15	Discuss in detail about the transformer tap changer with its types	Understand	CO 3	BPSB03.10
16	Discuss in detail about the converter control characteristics of HVDC system	Understand	CO 3	BPSB03.09
17	Discuss about conventional control strategies for Reactive power control in HVDC link. Enumerate the relative merits and demerits of constant current control and constant voltage control of HVDC link.	Understand	CO 3	BPSB03.09
18	Discus system control hierarchy for a HVDC-link and explain firing angle control in HYDC-values.	Remember	CO 3	BPSB03.10
19	Explain the un compounded inverter with neat sketches	Understand	CO 3	BPSB03.11
20	Why the delay angle and extinction angles are to be maintained to minimum value	Understand	CO 3	BPSB03.09
	UNIT IV			
	CONVERTER FAULTS AND PROTECTION			
	Part – A (Short Answer Questions)			
1	List out different faults in HVDC converters.	Understand	CO 4	BPSB03.14
2	What are the faults due to valves and controllers in converters?	Understand	CO 4	BPSB03.14
3	What is the nature and types of faults in /HVDC converters?	Understand	CO 4	BPSB03.14

4	What are arc back and arc through faults in converters?	Understand	CO 4	BPSB03.14
5	What are the sources of over voltages in converter station	Understand	CO 4	BPSB03.14
6	Explain briefly about commutation failure.	Understand	CO 4	BPSB03.14
7	What are the objectives of protection scheme	Understand	CO 4	BPSB03.14
8	What is the basic principle of over voltage protection	Understand	CO 4	BPSB03.14
9	Write a short note on surge arresters	Understand	CO 4	BPSB03.15
10	Explain about protection of HVDC converters against over currents.	Understand	CO 4	BPSB03.16
11	What is the importance of valve group in HVDC transmission?	Understand	CO 4	BPSB03.14
12	Draw a suitable diagram to explain the DC line protection	Understand	CO 4	BPSB03.16
13	Discuss briefly about misfire in converter faults of HVDC system	Understand	CO 4	BPSB03.14
14	Write a short note on quenching or current extinction.	Understand	CO 4	BPSB03.14
15	List out the effects of single commutation failure	Understand	CO 4	BPSB03.14
16	Write a short note on transient over voltages.	Remember	CO 4	BPSB03.14
17	Discuss about the over voltage caused by internal converter disturbances.	Understand	CO 4	BPSB03.15
18	What are the factors that depend on recovery of commutation failure?	Understand	CO 4	BPSB03.15
19	Discuss briefly about quenching in converter faults of HVDC system.	Understand	CO 4	BPSB03.15
20	What are the different faults that occur in HVDC converters?	Remember	CO 4	BPSB03.14
Part – B (Long Answer Questions)				
1	Why are converter faults caused? Discuss various types of faults against which protection has to be provided. Discuss protection against over currents in terms of selectivity, reliability and back up.	Understand	CO 4	BPSB03.16
2	Discuss corona loss in HVDC-link. Also explain R.I.-characteristics of HVDC-system.	Understand	CO 4	BPSB03.14
3	Explain for what reasons as a system planner, you consider the applications of HVDC in India? Explain the protection scheme for over currents in converters.	Understand	CO 4	BPSB03.16
4	Mention different types of converter faults, briefly explain with waveforms about commutation failure.	Understand	CO 4	BPSB03.14
5	Compute the maximum dip at the converter bus that will not result in a commutation failure. Assume that the voltage dip occurs at the instant immediately after firing the incoming valve. Consider symmetrical three phase voltage dip.	Understand	CO 4	BPSB03.14
6	Write a note on protection scheme against faults in voltage source converter.	Understand	CO 4	BPSB03.16
7	With the help of neat sketch of typical arrangement of surge arrester for converter pole explain over voltage protection in converter station	Understand	CO 4	BPSB03.15
8	Explain how transient over voltages are produced due to faults on DC side	Understand	CO 4	BPSB03.16
9	What are the over voltages due to disturbances on AC system side? Explain.	Understand	CO 4	BPSB03.14
10	Briefly explain over current protection scheme in the HVDC system.	Understand	CO 4	BPSB03.14
11	Briefly explain over voltage protection scheme in the HVDC system.	Understand	CO 4	BPSB03.15
12	What are transient over voltages due to disturbances on DC and AC system side line faults? Explain them.	Understand	CO 4	BPSB03.15
13	Explain the over voltages due to DC side line faults.	Understand	CO 4	BPSB03.14
14	Explain the over voltages due to AC side line faults.	Understand	CO 4	BPSB03.14
15	Write a short note on the following a) Over Voltages b) Over Currents	Understand	CO 4	BPSB03.14
16	Explain how transient over voltages are produced due to faults on AC side	Remember	CO 4	BPSB03.05
17	Explain the over voltages due to DC & AC side line faults.	Understand	CO 4	BPSB03.14
18	Write a short note on the following a) Commutation failure b) Surge arresters a) Transient over voltages	Understand	CO 4	BPSB03.14
19	What are the different causes of converter faults? Explain how the dc line is protected? Explain over voltage protection methods Converters.	Remember	CO 4	BPSB03.16
20	Briefly explain over current protection scheme in the HVDC system.	Understand	CO 4	BPSB03.16

UNIT V				
REACTIVE POWER MANAGEMENT				
Part - A (Short Answer Questions)				
1	Write the different types of AC/DC power flow	Understand	CO 5	BPSB03.17
2	What is unified method of DC power flow?	Understand	CO 5	BPSB03.17
3	What is sequential method of DC power flow?	Understand	CO 5	BPSB03.17
4	What are the advantages of variable elimination method over extended variable method?	Understand	CO 5	BPSB03.18
5	Draw the DC system model	Understand	CO 5	BPSB03.17
6	What are the additional constraints needed to include for ac-dc power flow	Understand	CO 5	BPSB03.17
7	List some essentials of power flow analysis	Understand	CO 5	BPSB03.17
8	Compare sequential and simultaneous methods of ac-dc power flow.	Understand	CO 5	BPSB03.17
9	Define Harmonic. How harmonics are generated?	Understand	CO 5	BPSB03.18
10	Mention the various sources of harmonic generation in HVDC system	Understand	CO 5	BPSB03.18
11	What are other methods of eliminating harmonics with HVDC system	Understand	CO 5	BPSB03.18
12	List out different types of AC/DC power flow	Understand	CO 5	BPSB03.17
13	What is unified method of DC power flow?	Understand	CO 5	BPSB03.17
14	What is sequential method of DC power flow?	Understand	CO 5	BPSB03.17
15	What are the components present in AC & DC filter?	Understand	CO 5	BPSB03.18
16	List out types of AC filters & Dc?	Remember	CO 5	BPSB03.18
17	What are the advantages of variable elimination method over extended variable method?	Remember	CO 5	BPSB03.18
18	Define single tuned filter? How will protect the filter?	Understand	CO 5	BPSB03.18
19	What are the major steps in the power flow analysis of MTDC-AC Systems	Understand	CO 5	BPSB03.17
20	Define AC and DC filters and list out the types of SC and DC filters	Remember	CO 5	BPSB03.18
Part - B (Long Answer Questions)				
1	Explain extended variable method of DC power flow	Understand	CO 5	BPSB03.17
2	Explain the variable elimination method of DC power flow	Understand	CO 5	BPSB03.17
3	Explain the sequential method of DC power flow. Draw the necessary flow chart.	Understand	CO 5	BPSB03.17
4	Explain about per unit system for DC quantities	Understand	CO 5	BPSB03.17
5	Compare sequential and unified methods of DC power flow.	Understand	CO 5	BPSB03.17
6	Explain unified method of DC power flow	Understand	CO 5	BPSB03.17
7	What are the additional constraints needed to include for ac-dc power flow?	Understand	CO 5	BPSB03.17
8	Compare sequential and simultaneous methods of ac-dc power flow	Understand	CO 5	BPSB03.17
9	Write a short note on the following: (a) Harmonic distortion (b) telephone Influence factor	Understand	CO 5	BPSB03.19
10	Mention the various sources of harmonic generation in HVDC systems and suggest methods to eliminate them	Understand	CO 5	BPSB03.18
11	Define telephone interference Factor and Explain how it varies with harmonic order.	Understand	CO 5	BPSB03.18
12	What are the order of harmonics present on the AC side of the VSC converter DC systems	Understand	CO 5	BPSB03.18
13	What are the filter configurations that are employed for HVDC Converter station? Give design aspect of one such filter	Understand	CO 5	BPSB03.18
14	Derive an equation for harmonic voltage and current for single tuned filter and discuss the influence of network admittance	Understand	CO 5	BPSB03.18
15	Give a detailed account of design aspects of following filters (a) Single tuned filter (b)Double tuned filter	Understand	CO 5	BPSB03.18
16	What are the different types of filters used on the AC side of an HVDC system? How are they located and arranged?	Understand	CO 5	BPSB03.18
17	State the various sources of harmonics generation in HVDC-VSC systems and mention the adverse effects caused by these harmonics	Understand	CO 5	BPSB03.20

18	With neat sketches, explain how a converter transformer is responsible for generation of harmonics and suggest various methods for minimizing them	Remember	CO 5	BPSB03.20
19	Explain the need to employ filter circuit in HVDC systems. Derive an Expression for minimum cost of tuned AC filters used in HVDC systems.	Understand	CO 5	BPSB03.18
20	Derive an equation for harmonic voltage and current for single tuned filter and discuss the influence of network admittance	Remember	CO 5	BPSB03.18

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