

PROGRAMME :M.E. POWER ELECTRONICS AND INDUSTRIAL DRIVES CURRICULUM

SEMESTER 1

Sl. No.	COURSE CODE	COURSE TITLE	L	T	P	C	PAGE No.
1.	SMT5104	Advanced Mathematics	4	0	0	4	1
2.	SEE5101	Analysis of Rectifiers and Choppers	4	0	0	4	2
3.	SEE5102	Analysis of Inverters	4	0	0	4	3
4.	SEE5103	Advanced Power Semiconductor Devices	4	0	0	4	4
5.	SEE5104	Solid State DC Drives	4	0	0	4	6
6.	SEE5105	PWM Techniques in Power Electronics	4	0	0	4	7
PRACTICAL							
1.	SEE6530	Power Electronics Lab	0	0	6	3	8
TOTAL CREDITS						27	

SEMESTER 2

Sl. No.	COURSE CODE	COURSE TITLE	L	T	P	C	PAGE No.
1.	SEE5106	Solid State AC Drives	4	0	0	4	8
2.	SEC5120	Embedded System Design	4	0	0	4	10
3.		Elective - 1	4	0	0	4	
4.		Elective - 2	4	0	0	4	
5.		Elective - 3	4	0	0	4	
PRACTICALS							
1.	SEE6531	Power Electronics Simulation Lab	0	0	6	3	11
TOTAL CREDITS						28	

SEMESTER 3

Sl. No.	COURSE CODE	COURSE TITLE	L	T	P	C	PAGE No.
1.	SEC5205	DSP Based System Design	4	0	0	4	12
2.		Elective - 4	4	0	0	4	
3.		Elective - 5	4	0	0	4	
4.		Elective - 6	4	0	0	4	
PRACTICAL							
1.	SEC6547	Embedded System for Power Electronics Lab	0	0	6	3	13
2.		Project Work Phase I					
TOTAL CREDITS						19	

L - LECTURE HOURS, T – TUTORIAL HOURS, P – PRACTICAL HOURS, C – CREDITS

SEMESTER 4

Sl. No.	COURSE CODE	COURSE TITLE	L	T	P	C	PAGE No.
1.	S34PROJ	Project Work - Phase I and II	0	0	40	20	

TOTAL CREDITS 20

TOTAL CREDITS FOR THE PROGRAM 94

ELECTIVE COURSES

Sl. No.	COURSE CODE	COURSE TITLE	L	T	P	C	PAGE No.
1.	SEE5601	Special Machines and Their Controllers	4	0	0	4	14
2.	SEE5602	Power Electronics in Power Systems	4	0	0	4	16
3.	SEE5603	Linear and Non Linear System Theory	4	0	0	4	18
4.	SEE5604	Analysis of Electrical Machines	4	0	0	4	19
5.	SEE5605	Industrial Management in Power Electronics	4	0	0	4	20
6.	SEE5606	Modelling and simulation in power electronics system	4	0	0	4	21
7.	SEE5607	Intelligent Control	4	0	0	4	22
8.	SEE5608	Power Electronics for Renewable Energy Systems	4	0	0	4	23
9.	SEE5109	Flexible AC Transmission	4	0	0	4	24
10.	SEE5623	High Voltage Direct Current Transmission	4	0	0	4	25

SEE5101	ANALYSIS OF RECTIFIERS AND CHOPPERS	L	T	P	Credits	Total Marks
		4	0	0	4	100

COURSE OBJECTIVE

- To analyze and comprehend the various operating modes of different configurations of power converters namely AC to DC, DC to DC and AC to AC converters.

UNIT 1 SINGLE PHASE RECTIFIERS**12 Hrs.**

Introduction – Principle of phase controlled converter operation – Single phase full converter with R, RL and RLE loads – Effect of Freewheeling diodes – Effect of source inductance – Single phase semi converter – Single phase dual converter – Single phase series converter.

UNIT 2 THREE PHASE RECTIFIERS**12 Hrs.**

Three phase half wave converter – Three phase semi converter – Three phase full converter with RL loads. – Effect of source and load inductance - Three phase dual converter – Power factor improvements

UNIT 3 DC CHOPPERS**12 Hrs.**

Introduction – Principles of step-down operation, step-down chopper with RL load – Principle of step-up operation with resistive load – Converter classification – Switching mode regulators – Analysis of buck, boost, buck boost and CUK converter – Comparison of regulators – Multi output boost converter.

UNIT 4 AC CHOPPERS**12 Hrs.**

Introduction – Principle of ON-OFF control – Principle of phase control – Single phase bidirectional controllers with resistive loads – Single phase controllers with Inductive loads – Three phase half wave and full wave controllers – Three phase bi-directional delta connected controllers. AC voltage controllers with PWM control

UNIT 5 CYCLOCONVERTER AND SPECIAL CONVERTERS**12 Hrs.**

Cycloconverters – Single phase step up and step down cycloconverter – Single phase to three phase cycloconverter – Three phase to single phase cycloconverter - Reduction of output Harmonics - Introduction to Matrix converter.

Max. 60 Hours**COURSE OUTCOMES**

On the completion of the course, student will be able to

- CO1 - Analyse single phase rectifiers with various loads
- CO2 - Analyse three phase rectifiers with various loads
- CO3 - Analyse DC chopper for a particular load
- CO4 - Design and analyse AC voltage controllers
- CO5 - Design various power converters

TEXT / REFERENCE BOOKS

- Rashid M.H, "Power Electronics Circuits, Devices & Applications", Pearson Education, 2013.
- Robert Erickson, "Fundamental of Power Electronics", Kluwer Academic Publishers, 6th printing 2004.
- P.S.Bimbra, " Power Electronics", Khanna Publishers, 5th Edition, 2014.
- Mohan .N, Undeland & Robbins, "Power Electronics Converters, Application & Design", John Wiley & Sons, Inc, 3rd edition, reprint 2009.
- P.C Sen, "Modern Power Electronics", S.Chand Ltd., 2005.
- M.D. Singh & K.B. Khanchandani, "Power Electronics", Tata Mc Graw Hill Publishing Company Limited, 2nd edition, 3rd reprint 2008.
- M.S.Jamil Asghar, "Power Electronics", PHI Learning Private Ltd, 2004, (3rd pinting 2004).
- V.R.Moorthi, "Power Electronics Drives, Circuits, and Industrial Applications," Oxford University press, First published in India 2005.

END SEMESTER EXAM QUESTION PAPER PATTERN**Max. Marks : 70****Exam Duration : 3 Hrs..****PART A** : 5 questions of 4 marks each – No choice**20 Marks****PART B** : 2 questions from each unit of internal choice, each carrying 10 marks**50 Marks**

SEE5102	ANALYSIS OF INVERTERS	L	T	P	Credits	Total Marks
		4	0	0	4	100

COURSE OBJECTIVES

- Ability to analyse and comprehend the various operating modes of different configurations of power converters
- Ability to design different single phase and three phase inverters.

UNIT 1 SINGLE PHASE INVERTER 12 Hrs.

Introduction – Principle of operation – Performance parameters – Single phase half bridge Inverters – Single phase full bridge Inverter – Single phase Series Inverter – Single phase parallel Inverter - Modified McMurray Inverter – McMurray Bedford half bridge and full Inverter Voltage control of single phase Inverters

UNIT 2 VOLTAGE SOURCE AND CURRENT SOURCE INVERTER 12 Hrs.

Three phase bridge Inverter with 180° and 120° mode of operation – Voltage control of three phase Inverters - Analysis of single phase and three phase auto sequential current source Inverter - Current source bridge Inverter– Harmonic Elimination Techniques.

UNIT 3 Z-SOURCE INVERTER 12 Hrs.

Comparison with VSI and CSI-Equivalent circuit and operation –Circuit analysis and calculation. Introduction to Quasi Z- source inverter-basic topology-Extended boost quasi Z- source inverter topologies

UNIT 4 RESONANT PULSE INVERTERS 12 Hrs.

Introduction – Series resonant Inverters with unidirectional and Bidirectional switches – Parallel resonant Inverters– Class E resonant Inverter - Zero current switching resonant converter – Zero voltage switching resonant converter– Two quadrant ZVS resonant converter – Resonant DC link Inverter.

UNIT 5 MULTILEVEL INVERTER 12 Hrs.

Multilevel concept – Diode clamped – Flying capacitor – Cascade type multilevel Inverters - Comparison of multi-level Inverters - Application of multilevel Inverters

Max. 60 Hours**COURSE OUTCOMES**

On the completion of the course, student will be able to

- CO1 - Understand the Operation of inverter for single phase and three phase circuits
- CO2 - Understand how to do the analysis for the inverter for harmonics.
- CO3 - Control the inverter output voltage by using the modulation techniques.
- CO4 - Design an inverter for a particular application and power level.
- CO5 - Understand the need for multi-level inverter and its operation.

TEXT / REFERENCE BOOKS

1. Rashid M.H, 'Power Electronics – Circuits, Devices & Applications', Pearson Education, 2013.
2. P.S.Bimbra, "Power Electronics", Khanna Publishers, 5th Edition, 2014.
3. Fang Lin Luo, Hong Ye, "Advanced DC/AC Inverters: Applications in Renewable Energy" CRC press, Taylor and Francis Group, 2013.
4. Mohan .N, Undeland & Robbins, "Power Electronics – Converters, Application & Design", John Wiley & Sons, Inc, 2nd Edition, New York, 2001.
5. P.C Sen, "Modern Power Electronics", S.Chand Ltd., 2005.
6. Rashid M.H., "Hand book on Power Electronics", Nihar Kularatna, Newnes, 1998.
7. M.D. Singh & K.B. Khanchandani, "Power Electronics", Tata Mc Graw Hill Publishing Company Limited, 2nd edition, 3rd reprint 2008.

END SEMESTER EXAM QUESTION PAPER PATTERN**Max. Marks : 70****Exam Duration : 3 Hrs..****PART A :** 5 questions of 4 marks each – No choice**20 Marks****PART B :** 2 questions from each unit of internal choice, each carrying 10 marks**50 Marks**

SEE5103	ADVANCED POWER SEMICONDUCTOR DEVICES	L	T	P	Credits	Total Marks
		4	0	0	4	100

COURSE OBJECTIVES

- To study the characteristics of advanced power semiconducting switches.
- To analyse the on-state and switching losses involved in the operation of power semiconducting switches.
- To study the firing and protection circuits of advanced power semiconducting switches.

UNIT 1 INTRODUCTION**12 Hrs.**

Power switching devices overview – Attributes of an ideal switch, application requirements, circuit symbols; Power handling capability – (SOA); Device selection strategy – On-state and switching losses – EMI due to switching – Power diodes - Types, forward and reverse characteristics, switching characteristics – Rating.

UNIT 2 CURRENT CONTROLLED DEVICES**12 Hrs.**

BJT's – Construction, static characteristics, switching characteristics; Negative temperature co-efficient and secondary breakdown; Power Darlington – Thyristors – Physical and electrical principle underlying operating mode, Two transistor analogy – concept of latching; Gate and switching characteristics; converter grade and inverter grade and other types; series and parallel operation; comparison of BJT and Thyristor – Steady state and dynamic models of BJT & Thyristor.

UNIT 3 VOLTAGE CONTROLLED DEVICES**12 Hrs.**

Power MOSFETs and IGBTs – Principle of voltage controlled devices, construction, types, static and switching characteristics, steady state and dynamic models of MOSFET and IGBTs – Basics of GTO, MCT, FCT, RCT and IGCT.

UNIT 4 FIRING AND PROTECTING CIRCUITS**12 Hrs.**

Necessity of isolation, pulse transformer, opto-coupler – Gate drive circuit: SCR, MOSFET, IGBTs and base driving for power BJT. - Over voltage, over current and gate protections; Design of snubbers.

UNIT 5 THERMAL PROTECTION**12 Hrs.**

Heat transfer – conduction, convection and radiation; Cooling – Liquid cooling, vapour – Phase cooling; Thermal modelling of power switching devices: Thermal equivalent circuit, Coupling of electrical & thermal components, heat sink types and design – Mounting types.

Max. 60 Hours**COURSE OUTCOMES**

On completion of the course, student will be able to

- CO1 - Understand the concept of Power semiconductor devices.
- CO2 - Study the performance of the current controlled and voltage controlled devices.
- CO3 - Explain the working of power semiconductor devices.
- CO4 - Evaluate the characteristics of all power semiconductor devices.
- CO5 - Examine the applications of power semiconductor devices.

TEXT / REFERENCE BOOKS

1. Mohan .N, Undeland and Robbins, "Power Electronics – Converters, Application & Design", John Wiley & Sons, Inc, 3rd Edition, Newyork, Reprint 2009.
2. Simon M.Sze & Kwok K.Ng, "Physics of Semiconductor Devices", A Wiley Inter science Publications, John Wiley and sons, New Jersey 3rd edition, 2007.
3. Rashid M.H., "Power Electronics Circuits, Devices and Applications ", Pearson Education, 2013.
4. M.D.Singh and K.B. Khanchandani, "Power Electronics", Tata McGraw Hill companies, Electrical and Electronics Engineering Series, 2nd Edition, 3rd reprint 2008.
5. Jayant Baliga, "Advanced Power Rectifier Concepts", Springer 2008.
6. Jayant Baliga, "Advanced High Voltage Power Devices Concepts", Springer 2010.

7. Dieter K.Schroder, "Semiconductor Material and Device Characterization", A John Wiley and Sons Inc Publication, New Jersey, 2006.
8. Robert F.Pierret, "Semiconductor Device Fundamentals", Pearson Education, 2nd impression 2008.
9. Donald A.Neamen, "Semiconductor Physics and Devices", McGraw Hill companies, Special Indian Edition, 2007.
10. P. C. Sen, "Power electronics", S.Chand Ltd., 2005.

END SEMESTER EXAM QUESTION PAPER PATTERN**Max. Marks : 70****PART A** : 5 questions of 4 marks each – No choice**PART B** : 2 questions from each unit of internal choice, each carrying 10 marks**Exam Duration : 3 Hrs.****20 Marks****50 Marks**

SEE5104	SOLID STATE DC DRIVES	L	T	P	Credits	Total Marks
		4	0	0	4	100

COURSE OBJECTIVE

- To study and analyze the operation of the converter / chopper fed DC drive, both qualitatively and quantitatively.
- To analyze and design the current and speed controllers for a closed loop solid state DC motor drive.

UNIT 1 REVIEW OF CONVENTIONAL DC DRIVES 12 Hrs.

Different techniques of speed control and methods of braking of series and separately excited DC motor, Ward Leonard speed control, Model and transfer function of series and separately excited DC motor.

UNIT 2 CONVERTER CONTROL OF DC MOTORS 12 Hrs.

Analysis of series and separately excited DC motor with single phase and three phase converters operating in different modes and configurations, Problems on DC machines fed by converter supplies, drive employing dual converter.

UNIT 3 CHOPPER CONTROL OF DC MOTORS 12 Hrs.

Introduction to time ratio control and frequency modulation; Class A,B,C,D and E chopper controlled DC motor – Performance analysis, multi-quadrant control – Chopper based implementation of braking schemes – Multiphase Chopper.

UNIT 4 DESIGN OF CONVERTER AND CHOPPER FOR DC DRIVES 12 Hrs.

Speed loop, P, PI, PID controllers, Current loop, Armature current reversal, Field current reversal - Digital controller and firing circuits, Simulation.

UNIT 5 INDUSTRIAL DC DRIVES 12 Hrs.

Introduction to Siemens drive system - Speed control with emf feedback & tachogenerator - Current measurement & Torque Measurement - Tuning of drive, Phase locked loop control of DC drives.

Max. 60 Hours**COURSE OUTCOMES**

On completion of the course, student will be able to

- CO1 - Understand the principle and modelling of DC motor and conventional drives.
- CO2 - Analyze the operation of single and three phase converter fed DC motor drives.
- CO3 - Analyze the operation of chopper fed DC motor drives.
- CO4 - Apply the various methods of closed loop speed control of DC drives.
- CO5 - Evaluate the performance of Siemens drive system for speed control of DC drives.

TEXT / REFERENCE BOOKS

1. Buxbaum, A., Schierau, K. and Staughem, "A Design of Control Systems for D.C. Drives", Springer - Verlag, Berlin, 1990.
2. Dubey, G.K., "Power Semiconductor Controlled Drives", Prentice Hall International, New Jersey, 1989.
3. Sen, P.C., "Thyristor D.C. Drives", Krieger Publishing Company, 1981.
4. Subrahmanyam, V., "Electric Drives Concept and Applications", Tata Mc Graw Hill Publishing Co., LTD., New Delhi, 1st reprint 2010.
5. Siemens's Course Material
6. R. Krishnan, "Electric Motor Drives: Modelling, Analysis, and Control", Prentice Hall; 1 edition, 2001.
7. Leonhard, Werner, "Control of Electrical Drives", 3rd ed. 2001, Springer 2001.

WEB SITES

1. www.automation.siemens.com
2. www.legacypower.net

END SEMESTER EXAM QUESTION PAPER PATTERN**Max. Marks : 70****Exam Duration : 3 Hrs.****PART A :** 5 questions of 4 marks each – No choice**20 Marks****PART B :** 2 questions from each unit of internal choice, each carrying 10 marks**50 Marks**

SEE5105	PWM TECHNIQUES IN POWER ELECTRONICS	L	T	P	Credits	Total Marks
		4	0	0	4	100

COURSE OBJECTIVES

- To analyse and comprehend the various PWM techniques of single and three phase inverters.
- To analyse and design space vector modulation.

UNIT 1 INVERTER CONTROL STRATEGY**12 Hrs.**

Introduction - Operation principle – Performance Parameters – PWM with Unipolar and Bipolar voltage switching – Effect of blanking time on voltage in PWM inverter – Voltage control of single phase inverter and three phase inverter

UNIT 2 ADVANCED PWM TECHNIQUES**12 Hrs.**

Different types of advanced modulation techniques - Analysis of third harmonics modulation – Output filter requirement for different PWM techniques - Comparison of PWM techniques – Harmonic reduction

UNIT 3 SPACE VECTOR MODULATION (SVM)**12 Hrs.**

Space Vector Modulation – Introduction - Concept of a space vector – Inverter switching states – Modulation Index - dq components for three phase sine wave source / level – Space vector sequence - Minimizing switching losses

UNIT 4 SVM MODULATION REGIONS**12 Hrs.**

Under modulation region – Derivation of V_a & V_b – Derivation of formula for T_a and T_b – Calculation of time values for T_a , T_b – Over modulation mode 1 and mode 2 – Modified reference voltage trajectory – Equation of various voltage segments.

UNIT 5 APPLICATIONS**12 Hrs.**

SVM implementation of three level diode clamped inverter – Three level inverter switching states, space vector diagram and modulation regions – Flow diagram for SVM implementation of three level inverter – Motor voltage and current waveforms for three level inverter in different regions – Five level diode clamped inverter – Switching states – Five level flying capacitor inverter – Switching states.

Max. 60 Hours**COURSE OUTCOMES**

On completion of the course, student will be able to

- CO1 - Analyse PWM techniques for single and three phase inverters.
- CO2 - Design of advanced PWM techniques.
- CO3 - Concept of space vector modulation.
- CO4 - Analyse space vector modulation regions.
- CO5 - Explain SVM implementation of three level inverter.

TEXT / REFERENCE BOOKS

- Mohammed H.Rashid, "Power Electronics – Circuits, Devices and Applications", Prentice Hall, Eastern Economy Edition, Fourth Edition, 2013.
- Bimal K Bose, "Modern Power Electronics and AC Drives", Prentice Hall, 1st Edition, 2001.
- Bimal Bose, "Power electronics and Motor Drives – Advances and Trends" – Academic Press, Elsevier, 2006.
- Hamid A.Toliyat & Steven G.Campbell, "DSP Based Electro Mechanical Motion Control", CRC press, 2004
- Grahame Holmes .D, Thomas A.Lipo, "Pulse Width Modulation for Power Converters, Principles and Practice" –Wiley IEEE Press – 2003.

END SEMESTER EXAM QUESTION PAPER PATTERN**Max. Marks : 70****Exam Duration : 3 Hrs.****PART A** : 5 questions of 4 marks each – No choice**20 Marks****PART B** : 2 questions from each unit of internal choice, each carrying 10 marks**50 Marks**

SEE6530	POWER ELECTRONICS LAB	L	T	P	Credits	Total Marks
		0	0	6	3	100

COURSE OBJECTIVES

- To design and analyze the various DC and AC drives.
- To generate the firing pulses for converters and inverters.
- To design three phase AC voltage regulator.

SUGGESTED LIST OF EXPERIMENTS

1. Single Phase Half and Full converter with R, RL, RLE loads.
2. Three Phase Half and Full converter with R, RL, RLE loads.
3. Speed control of PMDC motor using Voltage Commutated Chopper.
4. Speed control of PMDC motor using Current Commutated Chopper.
5. IGBT based speed control of three phase induction motor using PWM technique.
6. Three Phase AC voltage regulator.
7. Four quadrant chopper fed DC motor
8. Modified McMurray - Bedford Inverter.
9. Resonant DC to DC Converter.
10. single phase cycloconverter.

COURSE OUTCOMES

On completion of the course, student will be able to

- CO1 - Acquire knowledge about the half and full converter with R,RL and RLE load.
- CO2 - Determine the voltage for three phase AC voltage regulator.
- CO3 - Understand speed control of PMDC motor using VCC and CCC.
- CO4 - Analyze the performance characteristics of DC-DC converter.
- CO5 - Determine performance characteristics of various motor drives

SEE5106	SOLID STATE AC DRIVES	L	T	P	Credits	Total Marks
		4	0	0	4	100

COURSE OBJECTIVES

- Ability to understand and analyse the VSI and CSI fed drive
- Understand the speed control of induction motor by stator and rotor side control
- Ability to learn synchronous motor drives with fixed and variable frequency

UNIT 1 STATOR VOLTAGE CONTROL OF INDUCTION MOTOR 12 Hrs.

Torque, Slip characteristics, Equivalent circuit, Speed control – Variable Voltage, Variable Frequency, Constant V/F operation. Operation with different types of loads, Performance, Comparison of different AC power controllers, Speed reversal, Closed loop control.

UNIT 2 STATOR FREQUENCY CONTROL 13 HRS..

Operation of induction motor with non sinusoidal supply waveforms, Variable frequency operation of 3 phase induction motors, Constant flux operation, Current fed operation, Dynamic and regenerative braking of CSI and VSI fed drives.

UNIT 3 ROTOR RESISTANCE CONTROL 12 Hrs.

Torque, Slip characteristics, Types of rotor choppers, Torque equations, Constant torque operation, TRC strategy, Closed loop speed control.

UNIT 4 SLIP POWER RECOVERY SCHEME 12 Hrs.

Equivalent circuit, Torque equation, Torque - Slip characteristics - Power factor considerations - Sub synchronous operation and closed loop speed control, Vector or Field control - Direct Vector control.

UNIT 5 SYNCHRONOUS MOTOR DRIVES 11 Hrs.

Need for leading PF operation - Open loop VSI fed drive and its characteristics - Self control - Torque angle control - Power factor control - Brush less excitation system - Starting methods - Principles of vector control.

Max. 60 Hours**COURSE OUTCOMES**

On completion of the course, student will be able to

- CO1 - Operate and maintain solid state drives for speed control 3 phase induction motor
- CO2 - Exposed to different speed control methods in A.C motors using thyristor based control schemes.
- CO3 - Use vector control method for controlling the Induction motor drive.
- CO4 - Use vector control method for controlling the synchronous motor drive5.
- CO5 - Operate and maintain solid state drives for speed control of 3 phase Synchronous motor

TEXT / REFERENCE BOOKS

1. Murphy, J.M.D, Turnbull F.G., "Thyristor control of AC motors", Pergamon Press, 1973
2. B.K.Bose, "Power Electronics & AC drives", Academic Press, 2006.
3. Dubey .G.K., "Power Semiconductor Controlled Drives", Prentice Hall International, Newyork, 1989.
4. Dewan.S.B. Slemon, G.R. Straughen.A., "Power semiconductor drives", John wiley and sons, Newyork, 1984.
5. I.J.Nagrath & D.P.Kothari, "Electrical Machines", Tata McGraw-Hill Publications, 2006.
6. V.R.Moorthi, "Power Electronics Drives, Circuits, and Industrial Applications," Oxford University press, First published in India 2005, (sixth impression 2008).
7. R. Krishnan, "Electric Motor Drives: Modelling, Analysis, and Control", Prentice Hall, 2001.
8. Leonhard, Werner, "Control of Electrical Drives", 3rd ed. 2001, Springer 2001.
9. Paul C. Krause, Oleg Wasynczuk, Scott D. Sudhoff - "Analysis of Electric Machinery and Drive systems", IEEE press, 2013.

END SEMESTER EXAM QUESTION PAPER PATTERN**Max. Marks : 70****Exam Duration : 3 Hrs.****PART A : 5 questions of 4 marks each – No choice****20 Marks****PART B : 2 questions from each unit of internal choice, each carrying 10 marks****50 Marks**

SEC5120	EMBEDDED SYSTEM DESIGN	L	T	P	Credits	Total Marks
		4	0	0	4	100

COURSE OBJECTIVES

- To study the ARM processor and ARM instruction sets
- To understand RTOS concepts and Embedded networking concepts
- To understand basic ARM interfacing

UNIT 1 ARM ARCHITECTURE**12 Hrs.**

ARM Architecture ARM Design Philosophy, Registers, Program Status Register, Instruction Pipeline, Interrupts and Vector Table, Architecture Revision, ARM Processor Families.

UNIT 2 ARM INSTRUCTION SET**12 Hrs.**

Data Processing Instructions, Addressing Modes, Branch, Load, Store Instructions, PSR Instructions, Conditional Instructions. Thumb Instruction Set: Register Usage, Other Branch Instructions, Data Processing Instructions, Single Register and Multi Register Load -Store Instructions, Stack, Software Interrupt Instructions

UNIT 3 REAL TIME OPERATING SYSTEM**12 Hrs.**

Real time operating systems (RTOS) – real time kernel – OS tasks – task states – task scheduling – interrupt processing – clocking communication and synchronization – control blocks – memory requirements and control – kernel services.

UNIT 4 EMBEDDED NETWORKS**12 Hrs.**

Embedded Networks - Distributed Embedded Architecture – Hardware and Software Architectures, Networks for embedded systems– I2C, CAN Bus, Ethernet, Internet, Network–Based design– Communication Analysis, system performance Analysis, Hardware platform design, Allocation and scheduling, Design Example: Elevator Controller.

UNIT 5 SYSTEM DESIGN**12 Hrs.**

Switches and LED interfacing-LCD Display interfacing- Analog sensors interfacing for digital data conversion - Access control using analog keypad - Pulse width modulation technique for motor speed control

Max. 60 Hours**COURSE OUTCOMES**

On completion of the course, student will be able to

- CO1 - Gain significant knowledge about the complete architecture of an ARM processor.
- CO2 - Understand various instruction sets of ARM processor and their significance.
- CO3 - Analyze the various functionalities of Real Time Operating System
- CO4 - Compare and contrast the various embedded networking buses and justify their choice for an embedded system.
- CO5 - Design basic interfacing circuits using ARM processor.

TEXT / REFERENCE BOOKS

1. Andrew N.Sloss, Dominic Symes, Chris Wright, "ARM Systems Developer's Guide: Designing & Optimizing System Software", Elsevier, 2004.
2. Jonathan W. Valvano, " Embedded Microcomputer Systems: Real Time Interfacing", Cengage Learning, 2011
3. Wayne Wolf, "Computers as Components: Principles of Embedded Computing System Design", Morgan Kaufman Publishers, 2008.
4. C.M. Krishna, Kang G. Shin, "Real time systems", Mc-Graw Hill, 3rd reprint, 2010.
5. Herma K., "Real Time Systems: Design for Distributed Embedded Applications", Kluwer Academic Publishers, 1997.
6. William Hohl, "ARM Assembly Language, Fundamentals and Techniques", Taylor & Francis, 2009.

END SEMESTER EXAM QUESTION PAPER PATTERN**Max. Marks : 70****Exam Duration : 3 Hrs.****PART A : 5 Questions of 4 Marks each-No choice****20 Marks****PART B : 2 Questions from each unit with internal choice, each carrying 10 Marks****50 Marks**

SEE6531	POWER ELECTRONICS SIMULATION LAB	L	T	P	Credits	Total Marks
		0	0	6	3	100

COURSE OBJECTIVES

To make the students familiar with the digital tools used in generation of gate pulses for the power electronic switches using Matlab.

To make the students acquire knowledge on mathematical modeling of power electronic circuits and implementing the same using simulation tools.

To Implementation of closed loop system using hardware simulation.

SUGGESTED LIST OF EXPERIMENTS:

1. Open Loop Control of Separately Excited DC Motor.
2. Open Loop Control of DC Series Motor.
3. Closed Loop Control of Separately Excited DC Motor.
4. Thyristor Static and Dynamic Behavior
5. Simulation of Single Phase Semi Converter with motor load.
6. Simulation of Three Phase Converter with different loads.
7. Simulation of Single and Three phase PWM circuits.
8. AC – DC – AC PWM converter
9. Three Phase Matrix Converter
10. Chopper fed DC motor drive
11. Simulation of Single Phase Half Converter with different loads.
12. Three Phase Full Controlled Rectifier with R, RL loads.
13. Simulation of Buck Converter.
14. Simulation of Boost Converter
15. Simulation of Buck-Boost Converter.

COURSE OUTCOMES

On completion of the course, student will be able to

- CO1 - Acquire knowledge about the MATLAB/Simulink for open loop control of various DC.Motor.
- CO2 - Determine the voltage using Buck, Boost and Buck-Boost Converter.
- CO3 - Understand speed control of Induction motor and BLDC motor.
- CO4 - Analyze the performance of half, semi and fully controlled converter.
- CO5 - Determine performance characteristics of Inverter.

SEC5205	DSP BASED SYSTEM DESIGN	L	T	P	Credits	Total Marks
		4	0	0	4	100

COURSE OBJECTIVES

- To study the architectural details and assembly language programming concept for TMS320C24X DSP controller.
- To study the PWM waveform generation concept using event manager block in TMS320C24X .
- To study peripheral and communication interfacing for developing a DSP based system.

UNIT 1 INTRODUCTION**12 Hrs.**

TMS320 Family overview - The 320C24X Series of DSP Controllers - Architecture overview - C24X CPU Internal Bus structure - Memory - CALU – ARALU - Program control - Address modes

UNIT 2 INSTRUCTION SET**12 Hrs.**

Assembly Language Instruction - Instruction Set Summary - Instruction description - Accumulator, arithmetic and logic instruction - Auxiliary Register and Data page Pointer instructions - TREG, PREG and Multiply Instruction - Branch Instructions - Control Instructions - I/O and Memory instruction.

UNIT 3 EVENT MANAGER AND PWM GENERATION CIRCUITS**12 Hrs.**

Event manager (EV) functional blocks - General purpose timers - Compare units - PWM circuits associated with compare unit - PWM waveform generation with compare units and PWM circuits - Space vector PWM

UNIT 4 PERIPHERAL UNITS AND INTERRUPT STRUCTURE**12 Hrs.**

Capture unit - Quadrature Encoder pulse circuit - Event manager (EV) Interrupts - ON-Chip ADC – Overview - ADC clock - Pre-scalar – Calibration - Register Bit Description.

UNIT 5 SYSTEM DESIGN**12 Hrs.**

Serial Communication interface (SCI) for 2407 - SCI Communication format - Serial peripheral communication (SPI) SPI operation - CAN controller module - Overview of the CAN network - Getting started with code compose studio IDE - DSP Based system Design using PMDC - DSP-Based Control of Stepper Motors.

Max. 60 Hours**COURSE OUTCOMES**

On completion of the course, student will be able to

- CO1 - Understand the architecture of DSP core and its functionalities.
- CO2 - Write assembly language program for TMS320 Family.
- CO3 - Analyze the function of Event manager.
- CO4 - Acquire knowledge on operation of interrupts and peripherals.
- CO5 - Explore the possibilities of hardware implementation using DSP.

TEXT / REFERENCE BOOKS

1. Hamid A. Toliyat, Steven G.Campbell, "DSP- based Electromechanical Motion Control", CRC Press-2005.
2. Texas Instruments Inc, "Code Compare Studio white paper", www.ti.com, Texas Instruments Literature number SPRA 520.
3. Texas Instruments Inc, "TMS320LF / L1240XA DSP controller reference Guide- System and peripheral", www.ti.com, Texas Instruments Literature SPRU357A.
4. Texas Instruments Inc, "TMS320LF / L1240XA DSP controller reference Guide- CPU and Instruction set", www.ti.com, Texas Instruments Literature SPRU357A.

END SEMESTER EXAM QUESTION PAPER PATTERN**Max. Marks : 70****Exam Duration : 3 Hrs.****PART A** : 5 Questions of 4 Marks each – No choice**20 Marks****PART B** : 2 Questions from each unit with internal choice, each carrying 10 Marks -**50 Marks**

SEC6547	EMBEDDED SYSTEM FOR POWER ELECTRONICS LAB	L	T	P	Credits	Total Marks
		0	0	6	3	100

COURSE OBJECTIVES

- To understand the programming of ARM processor.
- To teach to interface ARM processor with other peripherals and system design using ARM processor.
- To apply the programming concepts related to TMS320C24X processor.
- To teach interfacing of DSP processor with other peripherals.
- To design DSP controller for speed control of DC motor.

SUGGESTED LIST OF EXPERIMENTS**EMBEDDED LAB Using ARM controller**

1. Arithmetic operations manipulation and logical operations
2. Interfacing of Switch
3. Interfacing of LED
4. Interfacing of LCD
5. Interfacing of DC Motor.

DSP LAB experiments using 2407 & associated peripherals

1. Perform 16 bit Addition, subtraction & multiplication.
2. Study on PWM generation using Timer 1,2,3.
3. Study of two PWM generation using full compare unit.
4. Study of six pulse PWM generation using full compare unit with dead band timer.
5. Perform Analog to Digital conversion for an Analog input.
6. Perform variable speed of DC Motor using TMS 3202407

COURSE OUTCOMES

On completion of the course, student will be able to

- CO1 - Understand the concepts and architecture of ARM controller.
- CO2 - Write simple programs for arm controller microcontroller.
- CO3 - Design of ARM controller for interfacing of dc motor, LED and LCD.
- CO4 - Understand the concepts of DSP processor.
- CO5 - Learn assembly language programming to generate PWM pulse using DSP processor.

SEE5601	SPECIAL MACHINES AND THEIR CONTROLLERS	L	T	P	Credits	Total Marks
		4	0	0	4	100

COURSE OBJECTIVES

- To impart knowledge on working principle and characteristics of switched reluctance motors, permanent magnet brushless motors, permanent magnet synchronous motors
- To study the working principle of novel motors

UNIT 1 STEPPER MOTORS**12 Hrs.**

Introduction to stepper motor - Constructional features and principle of operation - Single phase stepper motors - Modes of excitation - Characteristics - PM stepper motor, Hybrid Stepper motor - Construction and operation of Enhanced PMH stepper motor, Disc Magnet stepper motor, Electro hydraulic stepper motor - Drive circuits for stepper motor – Open loop control and Closed loop control of stepping motor - Single stack variable reluctance stepper motor - Multi-stack stepper motor – Electromagnetic torque developed in reluctance motor - Effect of saturation - Static and dynamic characteristics - Applications of stepper motor

UNIT 2 SWITCHED RELUCTANCE MOTORS**12 Hrs.**

Constructional features - Principle of operation - Torque equation - Power electronic converter circuits - Characteristics and control - Torque-speed Characteristics, Current sensing - Rotor position measurement and estimation- Sensor less rotor position estimation- Incremental inductance measurement and constant flux linkages method – Control of SRM for traction type load.

UNIT 3 PERMANENT MAGNET BRUSHLESS DC MOTORS**12 Hrs.**

Commutation in DC motor - Difference between mechanical and electronic commutators - Hall effect sensors -Optical sensors - Multiphase brushless motor - Square wave permanent magnet brushless motor drives - Torque and EMF equation – Torque - speed characteristics – Controllers

UNIT 4 PERMANENT MAGNET SYNCHRONOUS MOTORS**12 Hrs.**

Construction and operation of synchronous motors-d-q transformation and d-q model - Closed loop control in d-q reference frame - Vector control of permanent magnet synchronous motors - DTC of VSI and CSI fed electrically excited synchronous motors.

UNIT 5 NOVEL MOTORS**12 Hrs.**

Construction and operation of Written pole motors - Piezoelectric Motors - Bearingless motors - Slotless motors – Coreless Stator PM brushless motors: Disc type coreless motors, Cylindrical type motors with coreless stator winding.

Max. 60 Hours**COURSE OUTCOMES**

On completion of the course, student will be able to

- CO1 - Acquire knowledge about the fundamentals, characteristics and control of stepper motors.
- CO2 - Acquire knowledge about the fundamentals, characteristics and control of switched reluctance motors.
- CO3 - Analyze the characteristics and commutation circuits of permanent magnet brushless DC motors.
- CO4 - Acquire knowledge about the fundamentals, characteristics and control of permanent magnet Synchronous motors.
- CO5 - Acquire knowledge on Design considerations, performance analysis and speed control of Universal motor.

TEXT / REFERENCE BOOKS

1. Miller, T.J.E. "Brushless Permanent Magnet and Reluctance Motor Drives", Clarendon Press, Oxford, 1989.
2. Kenjo, T, "Stepping motors and their Microprocessor control", Clarendon Press, Oxford, 1989.
3. R.Krishnan, "Switched Reluctance Motor Drives – Modelling, Simulation, Analysis, Design and Applications", CRC Press, 2001.
4. J.F.Gieras, "Advancements In Electrical Machines", Springer Publishers, 2008

5. Kenjo, T and Nagamori, S, "Permanent Magnet and Brushless DC motors", Clarendon Press, Oxford, 1989.
6. K.Venkataratnam, "Special Electrical Machines", University Press Private Limited, 2008.
7. V.V.Athani, "Stepper Motors-Fundamentals, Applications and Design", New Age International (P) Limited, 1st Edition (Reprint 2013)

END SEMESTER EXAM QUESTION PAPER PATTERN

Max. Marks : 70

PART A : 5 questions of 4 marks each – No choice

PART B : 2 questions from each unit of internal choice, each carrying 10 marks

Exam Duration : 3 Hrs.

20 Marks

50 Marks

SEE5602	POWER ELECTRONICS IN POWER SYSTEMS	L	T	P	Credits	Total Marks
		4	0	0	4	100

COURSE OBJECTIVES

- To provide a chance for the students to learn more about FACTS devices, since they must be aware of reactive power compensation & power factor improvement.
- To impart more knowledge about the different power converter circuits which helps in energy storage and effective utilization

UNIT 1 LOAD COMPENSATION**12 Hrs.**

Introduction – Need for Compensation – Objectives in load compensation – Specifications of load compensator – Classification of compensation – Shunt & Series Compensation – Voltage Sag, Swell, Surges - Effects of Voltage Collapse

UNIT 2 INTRODUCTION TO FACTS DEVICES**12 Hrs.**

Thyristor Controlled Reactor (TCR) – Thyristor Switched Capacitor (TSC) – Saturable Reactor – Saturated Reactor Compensator – Static VAR Compensator (SVC) – Thyristor Controlled Series Capacitor (TCSC) – STATCOM – Dynamic Voltage Restorer (DVR)

UNIT 3 HARMONICS CONTROL & POWER FACTOR IMPROVEMENT**12 Hrs.**

Reactive power variation for fully controlled converter – Half controlled converter – Fully controlled converter with controlled freewheeling – Methods of employing natural commutation – Methods of employing forced commutation – Implementation of forced commutation

UNIT 4 VOLTAGE CONTROL USING STATIC TAP CHANGER**12 Hrs.**

Introduction to voltage regulators – Single Phase voltage controllers – Sequence control of AC voltage controllers – Manually controlled voltage regulator (Conventional Methods) – Static Tap changer using thyristors.

UNIT 5 UNINTERRUPTIBLE POWER SUPPLY SYSTEMS**12 Hrs.**

Switched mode power supply (SMPS) – Parallel UPS – Rotating UPS – Static UPS types – UPS using resonant power converters – High voltage DC transmission – Static circuit breakers

Max. 60 Hours**COURSE OUTCOMES**

On completion of the course, student will be able to

- CO1 - Remember the importance of reactive power compensation and power factor improvement.
- CO2 - Understand the various FACTS devices and its role in compensation.
- CO3 - Apply various methods of commutation for converters.
- CO4 - Categorise different tap changing transformer and its applications.
- CO5 - Justify the importance of UPS and SMPS.

TEXT / REFERENCE BOOKS

- Miller.T.J.E, "Reactive Power Control in Electric Systems", Wiley-Interscience, New York, 1982.
- G.K.Dubey, "Thyristorised Power Controllers", New Age International Publishers, 2nd Edition (2012).
- Dr.P.S.Bimbhra, "Power Electronics", Khanna Publishers, 5th Edition, 2014.
- R. Mohan Mathur, Rajiv K. Varma, "Thyristor-based Facts Controllers for Electrical Transmission systems", Wiley-IEEE, 2002.
- P.C.Sen, "Power Electronics", Tata Mc Graw Hill, 2008.
- "Static compensator for AC power systems", Prac.IEE Vol 128, pt.c, Nov 1981, pp362-406.
- "A static alternative to the Transformers on Load tap Changing", IEEE Trans. On PAS, Vol 101, Sep.1982, pp 3091-3095.
- K. R. Padiyar, "FACTS Controllers in Power Transmission and Distribution", New Age International, 2007(Reprint 2013).

9. Narain G Hingorani and Laszlo Gyugyi, "Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems", Wiley-IEEE Press, 1999.

END SEMESTER EXAM QUESTION PAPER PATTERN

Max. Marks : 70

PART A : 5 questions of 4 marks each – No choice

PART B : 2 questions from each unit of internal choice, each carrying 10 marks

Exam Duration : 3 Hrs.

20 Marks

50 Marks

SEE5607	INTELLIGENT CONTROL	L	T	P	Credits	Total Marks
		4	0	0	4	100

COURSE OBJECTIVE

- This subject aims to furnish ideas related to neural network, fuzzy logic, genetic algorithm and its implementation ideas in electric drives to students to develop and learn issues related to the power converters

UNIT 1 INTRODUCTION**12 Hrs.**

Approaches to intelligent control. Architecture for intelligent control. Symbolic reasoning system, rule – based systems, the AI approach. Knowledge representation. Expert systems.

UNIT 2 ARTIFICIAL NEURAL NETWORKS**12 Hrs.**

Concept of Artificial Neural Networks and its basic mathematical model, McCulloch - Pitts neuron model, simple Perceptron, Adaline and Madaline, Feed-forward Multilayer Perceptron. Learning and Training the neural network. Hopfield network, Self Organizing network and Recurrent network- Back propagation networks. Principal Component analysis and wavelet transformations related to power electronics.

UNIT 3 OPTIMIZATION TECHNIQUES**12 Hrs..**

Objective function-Uni modal-Multi model Constraints-Fitness Function-Operators Genetic Algorithm, Tabu search, ant-colony search

UNIT 4 FUZZY LOGIC SYSTEM**12 Hrs..**

Introduction to crisp sets and fuzzy sets, basic fuzzy set operation and approximate reasoning. Introduction to fuzzy logic modelling and control. Fuzzification, inferencing, defuzzification. Fuzzy knowledge and rule bases. Fuzzy modelling and control schemes for nonlinear systems. Self-organizing fuzzy logic control- Neuro fuzzy controllers.

UNIT 5 APPLICATION (QUANTITATIVE APPROACH ONLY)**12 Hrs..**

GA application to power electronics for the harmonic reduction in inverter. Case studies: Harmonic elimination method using Neural Network – V/F Speed control of an Induction Motor with Neural network based SVM modulator for inverter. Neuro Fuzzy Based efficiency optimized control-Stability analysis of fuzzy control systems.

Max. 60 Hours**COURSE OUTCOMES**

On completion of the course, student will be able to

- CO1 - Familiarize the basis and architecture of intelligent control system.
- CO2 - Explain the artificial neural networks by using different learning rule.
- CO3 - Predict and analyze the optimization techniques by applying genetic algorithm.
- CO4 - Describe fuzzy methods of analyzing problems which involve incomplete or vague criteria rather crisp values.
- CO5 - Evaluate the harmonics elimination by implementing the application of genetic algorithm and neural networks.

TEXT / REFERENCE BOOKS

- S.N.Sivanandam, S.Sumathi and S.N.Deepa, "Introduction to Neural Networks using MATLAB 6.0", Mc Graw Hill Publishing companies Limited, 3rd Edition 2008.
- Lawrence V.Fansett, "Fundamentals of Neural Networks: Architectures, Algorithms & Applications", Prentice Hall, 1994.
- Simopn S.Haykin, "Neural Networks: A Comprehensive Foundation", Macmillan, 1994.
- S.Rajasekaran, G.A.Vijayalakshmi Pai, "Neural Networks, Fuzzy Logic & Genetic Algorithms: Synthesis & Applications", PHI, 3rd Edition 2007.
- S.N.Sivanandam & S.N.Deepa, "Introduction to genetic Algorithms", Springer Publications 2007.

END SEMESTER EXAM QUESTION PAPER PATTERN**Max. Marks : 70****Exam Duration : 3 Hrs.****PART A** : 5 questions of 4 marks each – No choice**20 Marks****PART B** : 2 questions from each unit of internal choice, each carrying 10 marks**50 Marks**

SEE5608	POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS	L	T	P	Credits	Total Marks
		4	0	0	4	100

COURSE OBJECTIVES:

- To provide the knowledge of photo voltaic system and wind energy system
- To learn the hybrid connected PV and wind energy system with diesel power plant

UNIT 1 INTRODUCTION**12 Hrs.**

Overview of Indian energy scenario – Energy sources and availability – Energy crisis – Need to develop new energy technologies – Solar energy availability in India – Wind survey in India – Emerging trends in electrical energy utility – Energy and environment.

UNIT 2 POWER ELECTRONICS FOR PHOTOVOLTIC SYSTEMS**12 Hrs.**

Solar cell fundamentals – Conversion of sunlight to electricity – Cell performance – Basics of photovoltaic – Types of PV power systems – Standalone PV systems – Battery charging – PV charge controllers – Maximum Power Point Tracking (MPPT) – Inverters for stand alone PV systems – Solar water pumping – Power conditioning unit for PV water pumping.

UNIT 3 HYBRID AND GRID CONNECTED PV SYSTEMS**12 Hrs.**

PV Diesel hybrid systems – Control of PV – Diesel hybrid system – Grid connected PV systems – Inverters for grid connected applications – Inverter – Inverter types – Power control through PV inverters – System configuration – Grid inverter characteristics.

UNIT 4 POWER ELECTRONICS FOR WIND POWER SYSTEM**12 Hrs.**

Basics of wind power – Types of wind turbines – Types of wind generators – Types of wind power systems – Stand alone wind diesel hybrid systems – Grid connected wind energy systems.

UNIT 5 SYSTEM MANAGEMENT OF WIND ENERGY CONVERTER**12 Hrs.**

Prototype development – Control circuitry – Microcontroller – Complex programmable logic device – Gate driver circuitry for wind energy applications.

Max. 60 Hours**COURSE OUTCOMES**

On completion of the course, student will be able to

- CO1 - Understand the concepts of photovoltaic system and wind energy system.
- CO2 - Apply power electronics for standalone photovoltaic systems.
- CO3 - Design a hybrid grid connected PV systems.
- CO4 - Develop a power electronics based grid connected wind energy system.
- CO5 - Analyse gate driver circuitry for wind energy applications.

TEXT / REFERENCE BOOKS

- Rashid. M. H, "Power Electronics Handbook", Academic press, 2001.
- Erickson. R., Angkrtitrakul. S, Al – Nasean. O and Lujan. G, "Novel power electronics systems for wind energy applications" – Final report, National Renewable Energy Laboratory, Colorado, US. – Aug 24, 1999 – Nov 30, 2002.
- Rai. G. D, "Non conventional energy sources", Khanna publishers, 4th Edition 2000.
- B.H.Khan, "Non Conventional Energy Resources", Tata Mc GrawHill, 2nd Edition 2009.
- J.K.Manwell, J.G.McGowan, A.L.Rogers, "Wind energy explained – Theory Design and applications", John Wiley & Sons, 2nd Edition 2009.

END SEMESTER EXAM QUESTION PAPER PATTERN**Max. Marks : 70****Exam Duration : 3 Hrs.****PART A :** 5 questions of 4 marks each – No choice**20 Marks****PART B :** 2 questions from each unit of internal choice, each carrying 10 marks**50 Marks**

SEE5109	FLEXIBLE AC TRANSMISSION	L	T	P	Credits	Total Marks
		4	0	0	4	100

COURSE OBJECTIVES

- To have an understanding in various Reactive power Compensators
- To model and implement the FACTS controllers in enhancement of power system performance
- To have a knowledge in coordination of FACTS controllers

UNIT 1 INTRODUCTION**12 Hrs.**

Concepts of reactive power – Load compensation – System compensation – Midpoint conditions of a symmetrical line – Passive shunt and series compensation – Synchronous condenser – Saturated reactor – Phase shifting transformer – Concept of FACTS devices.

UNIT 2 STATIC VAR COMPENSATOR (SVC)**12 Hrs.**

Thyristor Controlled Reactor (TCR) - Thyristor Switched Reactor (TSR) - Thyristor Switched Capacitor (TSC) - Fixed Capacitor - Thyristor Controlled Reactor (FC-TCR) - Thyristor Switched Capacitor - Thyristor Controlled Reactor (TSC -TCR) – V-I Characteristics of Static Var Compensator (SVC) - Advantages of slope in dynamic Characteristic – Voltage control by SVC – Design of SCV voltage regulator. Applications: Increase in power transfer capacity – Enhancement of transient stability – Prevention of voltage instability.

UNIT 3 THYRISTOR CONTROLLED SERIES CAPACITOR (TCSC)**12 Hrs.**

Concept of series compensation - Thyristor Controlled Series Capacitor (TCSC) controller: Basic principle – Modes of Operation – Advantages - Analysis – Capability Characteristic, Modelling of TCSC, Applications: Open loop and closed loop control – Improvement of the system stability limit – Enhancement of system damping- Concept of Advanced Series Capacitor (ASC).

UNIT 4 EMERGING FACTS CONTROLLER**12 Hrs.**

Static Synchronous Compensator (STATCOM): Principle of Operation – V-I Characteristic – Harmonic performance – Steady state model. SSSC: principle of operation – Control system. Unified Power Flow Controller (UPFC): Principle of Operation – Injection model. Interline Power Flow Controller (IPFC): Principle of Operation – Control structure - Hybrid Power Flow Controller (HPFC)- Evaluation of different FACTS controllers.

UNIT 5 SUB SYNCHRONOUS RESONANCE (SSR)**12 Hrs.**

NGH-SSR damping scheme – Thyristor controlled braking resistor (TCBR) – Coordination of Multiple Controllers using Linear Control Techniques – Approximate multimodal decomposition method for the design of FACTS controllers.

Max. 60 Hours**COURSE OUTCOMES**

On completion of the course, student will be able to

- CO1 - Acquire knowledge about reactive power compensation.
- CO2 - Analyse the operation and control of static var compensator.
- CO3 - Ability to model Thyristor controlled series capacitor.
- CO4 - Gain knowledge of emerging FACTS controller.
- CO5 - Coordination of multiple controllers.

TEXT / REFERENCE BOOKS

1. R. Mohan Mathur, Rajiv K. Varma, "Thyristor-based facts controllers for electrical transmission systems", Wiley-IEEE, 2002.
2. K.R. Padiyar, "Facts Controllers in Power Transmission & Distribution", New Age International Publishers.
3. Enrique Acha, Claudio R. Fuerte-Esquivel, Hugo Ambriz-Perez, Cesar Angeles-Camacho, "FACTS: Modelling and Simulation in Power Networks", John Wiley & Sons Ltd., 2004.
4. S. Sivanagaraju, S.Sathyabarayana, "Electric Power Transmission and Distribution", Pearson Education, 2009.
5. Kalyan K. Sen & Mey Ling Sen, "Introduction to FACTS controllers: Theory, Modelling, and Applications", Wiley-IEEE, 2009.
6. Narain G. Hingorani, Laszlo Gyugyi, "Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems", IEEE Press Standard Publishers Distributors, 2000.
7. M.Noroozian et.al "Use of UPFC for optimal power flow control", Transactions on Power Delivery, Vol.12, No.4, oct 1997, pp 1629-1634

END SEMESTER EXAM QUESTION PAPER PATTERN**Max. Marks : 70****Exam Duration : 3 Hrs.****PART A** : 5 questions of 4 marks each – No choice**20 Marks****PART B** : 2 questions from each unit of internal choice, each carrying 10 marks**50 Marks**

SEE5623	HIGH VOLTAGE DIRECT CURRENT TRANSMISSION	L	T	P	Credits	Total Marks
		4	0	0	4	100

COURSE OBJECTIVES

- To impart knowledge on operation, modelling and control of HVDC link.

UNIT 1 DC POWER TRANSMISSION TECHNOLOGY 12 Hrs.

Introduction - Comparison of AC and DC transmission - Application of DC transmission – Description of DC transmission system - Planning for HVDC transmission - Modern trends in DC transmission.

UNIT 2 ANALYSIS OF HVDC CONVERTERS 12 Hrs.

Pulse number, choice of converter configuration - Simplified analysis of Graetz Circuit - Converter bridge characteristics – Characteristics of a twelve pulse converter - Detailed analysis of converters.

UNIT 3 CONVERTER AND HVDC SYSTEM CONTROL 12 Hrs.

General principles of DC link control - Converter control characteristics - System control hierarchy - Firing angle control - Current and extinction angle control - Starting and stopping of DC link - Power control - Higher level controllers - Telecommunication requirements.

UNIT 4 MULTITERMINAL DC SYSTEM 12 Hrs.

Multiterminal DC systems: Introduction – Potential application of MTDC systems – Types of MTDC systems – Control and protection of MTDC systems - Operation of HVDC breaker.

UNIT 5 HARMONICS AND CONVERTER COMPONENT MODEL 12 Hrs.

Introduction - Generation of harmonics - Design of AC filters - DC filters - Carrier frequency and RI noise. Converter model - Continuous time model - Discrete time converter model - Detailed model of the converter.

Max. 60 Hours**COURSE OUTCOMES**

On completion of the course, student will be able to

- CO1 - Overview of Power system, need of DC transmission, and various plans to transmit HVDC.
- CO2 - Analysis of various converter and identification of suitable converter for HVDC transmission.
- CO3 - Identification of better control system of the converter for HVDC system.
- CO4 - Understanding about the different types of DC system and protection methods of MTDC system.
- CO5 - Analysis of various converter model components performance.

TEXT / REFERENCE BOOKS

- Padiyar, K.R., "HVDC Power Transmission System", New Age International (P) Ltd. 1st edition, 1990.
- Edward Wilson Kimbark, "Direct Current Transmission", Vol. I, Wiley Interscience, New York, London, Sydney, 1971.
- Rakosh Das Begamudre, "Extra high voltage AC transmission Engineering", New Age International (P) Ltd., New Delhi, 3rd edition, 2006
- Arrillaga, Jos., "High Voltage Direct Current Transmission", IEE Power and Energy series, 1998.
- Vijay K. Sood, "HVDC & FACTS Controllers – Application of static converters in power system", Kluwer academic publishers, 2004
- Jos Arrillaga, Y.H.Liu, N.R. Watson, "Flexible Power Transmission" – The HVDC option-John Wiley & sons Ltd, 2007.

END SEMESTER EXAM QUESTION PAPER PATTERN**Max. Marks : 70****Exam Duration : 3 Hrs.****PART A :** 5 questions of 4 marks each – No choice**20 Marks****PART B :** 2 questions from each unit of internal choice, each carrying 10 marks**50 Marks**