M. Tech

IN

POWER ELECTRONICS

CURRICULUM AND SYLLABI

(Applicable from 2023 admission onwards)

Department of Electrical Engineering
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
Kozhikode - 673601, KERALA, INDIA

The Program Educational Objectives (PEOs) of M. Tech in Power Electronics

PEO1	Apply enhanced knowledge and skills in the area of power electronics so as to excel in various sectors in modern power industry / utility / transportation electrification and / or teaching and / or higher education and / or research.
PEO2	Engage in design of novel products and strategic solutions to real life problems in the areas of power electronics that are technically sound, economically feasible and socially acceptable.
PEO3	Exhibit professionalism, keep up ethics in profession and demonstrate communication skills, leadership qualities as well as willingness to work in groups.

Programme Outcomes (POs) of M. Tech in Power Electronics

PO1	Ability to independently carry out research / investigation and development work to solve practical problems
PO2	Ability to write and present a substantial technical report / document
PO3	Ability to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
PO4	Ability to provide engineering solutions to the problems pertaining to Power Electronics by utilizing the acquired knowledge and to take up project management issues including financial and administrative challenges in the power electronics space, having multidisciplinary nature.
PO5	Willingness and ability for the sustentation of professional ethics and social values while carrying out the responsibilities as a Power Electronics engineer/researcher in devising solutions to real life engineering problems in an independent manner, with a perspective to sustained lifelong learning process.

CURRICULUM

Total credits for completing the M. Tech programme in Power Electronics is 75.

COURSE CATEGORIES AND CREDIT REQUIREMENTS:

The structure of M.Tech. programme shall have the following Course Categories:

Sl. No.	Course Category	Minimum Credits
1.	Program Core (PC)	26
2.	Program Electives (PE)	12
3.	Institute Elective (IE)	2
4.	Projects	35

The effort to be put in by the student is indicated in the tables below as follows:
L: Lecture (One unit is of 50 minute duration)
T: Tutorial (One unit is of 50 minute duration)
P: Practical (One unit is of one hour duration)
O: Outside the class effort / self-study (One unit is of one hour duration)

PROGRAMME STRUCTURE

Semester I

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA6003E	Mathematical Methods for Power Engineering	3	0	0	6	3	PC
2.	EE6301E	Power Electronic Circuits-I	3	0	0	6	3	PC
3.	EE6302E	Dynamics of Electrical Machines	3	0	0	6	3	PC
4.	EE6303E	Modern Digital Signal Processors	3	0	0	6	3	PC
5.		Programme Elective-1	3	0	0	6	3	PE
6.		Programme Elective-2	3	0	0	6	3	PE
7.	EE6391E	Power Electronics Lab	0	0	2	1	1	PC
8.		Institute Elective	2	0	0	4	2	IE
		Total	**20**	**0**	**2**	**41**	**21**	**--**

Semester II

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	EE6311E	Power Electronic Circuits-II	3	0	0	6	3	PC
2.	EE6312E	Power Electronic Drives	3	0	0	6	3	PC
3.	EE6313E	Digital Control of Power Electronic Converters	2	0	2	5	3	PC
4.	EE6314E	Switched Mode Power Conversion	3	0	0	6	3	PC
5.		Programme Elective-3	3	0	0	6	3	PE
6.		Programme Elective-4	3	0	0	6	3	PE
7.	EE6392E	Seminar	0	0	2	1	1	PC
8.	EE6393E	Project Phase I	0	0	3	3	2	PC
		Total	**17**	**0**	**7**	**39**	**21**	**--**

Semester III

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	EE7391E	Project Phase II*	0	0	6	3	3	PC
2.	EE7392E	Project Phase III	0	0	30	15	15	PC
		Total	**0**	**0**	**36**	**18**	**18**	**--**

** to be completed during Summer*

Semester IV

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	EE7393E	Project Phase IV	0	0	30	15	15	PC
		Total	**0**	**0**	**30**	**15**	**15**	**--**

List of Electives

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1	EE6321E	Power Semiconductor Devices and Modelling	3	0	0	6	3
2	EE6322E	Static VAR Controllers and Harmonic Filtering	3	0	0	6	3
3	EE6323E	Digital Simulation of Power Electronic Systems	3	0	0	6	3

4	EE6324E	Advanced Control of Inverter-fed Induction Motor Drives	3	0	0	6	3
5	EE6325E	Linear and Digital Electronics	3	0	0	6	3
6	EE6326E	Power Electronic Drives for Special Machines	3	0	0	6	3
7	EE6327E	Computer Aided Design of Electromagnetic Systems	2	0	2	5	3
8	EE6328E	Electric Vehicle System Engineering	3	0	0	6	3
9	EE6329E	Advanced Microprocessor based Systems	3	0	0	6	3
10	EE6221E	Power Quality Issues and Remedial Measures	3	0	0	6	3
11	EE6225E	Smart Grid Technologies	3	0	0	6	3
12	EE6226E	Distributed Generation and Micro-Grids	3	0	0	6	3
13	EE6230E	Development and Evaluation of Power Projects	3	0	0	6	3
14	EE6522E	HVDC Transmission	3	0	0	6	3
15	EE6525E	Electromagnetic Interference and Compatibility	3	0	0	6	3

List of Institute Electives

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1	ZZ6001E	Research Methodology	2	0	0	4	2
2	MS6174E	Technical Communication and Writing	2	1	0	3	2
3	IE6001E	Entrepreneurship Development	2	0	0	4	2

*** List of Electives offered in each semester will be announced by the Department. Any other PG level course approved by the senate offered in the Institute can also be credited as Programme Electives with the prior approval of the Programme Coordinator.*

MA6003E MATHEMATICAL METHODS FOR POWER ENGINEERING

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Solve systems of linear equations using the language of matrices.
CO2: Apply the concept of vectors spaces, eigenvalues and eigenvectors.
CO3: Solve unconstrained and constrained nonlinear programming problems.
CO4: Determine approximate solutions to transcendental equations and system of equations usingnumerical methods.
CO5: Evaluate definite integrals and solve ODEs using numerical methods.

Linear Algebra

System of linear equations: Range space and Null space of a matrix, Rank of a matrix, Existence and uniqueness of solution of the system of linear equations, Dimension of the Solution Space associated withthe system of linear equations.
Vector Spaces: Definition of Vector space, Sub spaces, linearly independence and dependence, linear Span, Basis, Dimension.
Eigenvalues and Eigenvectors, Properties of eigenvalues and eigenvectors, Similarity matrices, Complex matrices.

Optimization Methods

Unconstrained one-dimensional optimization techniques, Necessary and sufficient conditions, Unrestrictedsearch methods, Fibonacci and Golden section method.
Unconstrained n dimensional optimization techniques, Descent methods, Steepest descent, conjugate gradient. Constrained optimization Techniques, Necessary and sufficient conditions, Equality and inequalityconstraints, Kuhn-Tucker conditions, Gradient projection method.

Numerical Methods

Solution of algebraic and transcendental equations: fixed point iteration method, Newton Raphson method.Solution of linear system of equations, Gauss elimination method, Pivoting, Gauss Jordan method, Iterativemethods: Gauss Jacobi, Gauss Seidel and relaxation method, Newton's method for nonlinear system of equations. Numerical Integration: Trapezoidal and Simpson's rule, Composite integration methods, Gauss quadrature methods. Numerical Solution of Ordinary Differential Equations: Euler's method, Euler's modified method, Taylor's method, Runge-Kutta method, Multistep methods, Milne's and Adams' methods, Predictor-Corrector methods.

References:

1. G. Strang, *Introduction to Linear Algebra*, Wellesley MA: Cambridge Press, 2016.
2. D M Simmons, *Nonlinear Programming for Operations Research*, Prentice Hall, 1975.
3. G Mohan and Kusum Deep, *Optimization Techniques*, New age International Publishers, 2009.
4. Jain M.K., Iyengar S.R.K., Jain R.K., *Numerical methods for Scientific and EngineeringComputation*, 8th edition, New Age International (P) Ltd, 2022.

EE6301E POWER ELECTRONIC CIRCUITS – I

Pre-requisites: **NIL**

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Analyse and design diode rectifiers and filter circuits
CO2: Design and implement various types of controlled rectifiers
CO3: Explain about various PWM techniques for 2-level DC to AC converters
CO4: Evaluate and design inverters with advanced PWM techniques
CO5: Design current controlled voltage source inverters

Line Frequency Uncontrolled and Controlled Rectifiers

Single Phase Rectifiers: Half Wave Controlled Rectifier with R, RL, RLE loads, with Freewheeling diode. Full Wave Controlled Rectifier with various types of loads. Half Controlled and Full Controlled Bridges with passive and active loads - Input Line Current Harmonics and Power Factor- Inverter Mode of Operation.
Three Phase Rectifiers**:** Half Wave Controlled rectifier with RL Load, Half Controlled Bridge with RL Load, Fully Controlled Bridge with RL Load. Input Side Current Harmonics and Power Factor - Dual Converters. Circulating Current Mode and Non-Circulating Current Mode.

C filter and LC filter design for Single Phase diode rectifiers. Three Phase half wave rectifier with resistive load. Three phase full wave rectifier. Double Y type rectifier. Three Phase Rectifier Circuits. Input line current harmonics and power factor. Line Notching and its control.

Switch-Mode DC-AC Inverters
Basic Concepts. Single Phase Inverters. PWM Principles. Sinusoidal Pulse Width Modulation in Single Phase Inverters. Choice of carrier frequency in SPWM. Spectral Content of output. 3rd Harmonic injection to enhancethe source utilization. Bipolar and Unipolar Switching in SPWM - Blanking Time Maximum Attainable DC Voltage Switch Utilization. Reverse Recovery Problem and Carrier Frequency Selection. Output Side Filter Requirements and Filter Design - Ripple in the Inverter Output - DC Side Current.

Three Phase Inverters -Three Phase Square Wave /Stepped Wave Inverters. Three Phase SPWM Inverters.
Choice of Carrier Frequency in Three Phase SPWM Inverters. Output Filters. DC Side Current. Effect of Blanking Time on Inverter Output Voltage.

Introduction to High Power Converters
Converters for High Power Applications: Standard Modulation Strategies - Programmed Harmonic Elimination. Multi-Pulse Converters and Interface Magnetics - Space Vector Modulation – Minimum ripple current PWM method. Current Regulated Inverter – Current Regulated PWM Voltage Source Inverters. Methods of Current Control. Hysteresis Control. Variable Band Hysteresis Control. Fixed Switching Frequency Current Control Methods. Switching Frequency Vs accuracy of Current Regulation Areas of application of Current Regulated VSI.

References:

1. Ned Mohan *Power Electronics: Converters, Applications, and Design*, John Wiley and Sons, 2006.
2. P.C. Sen, *Power Electronics*, Tata McGraw Hill, 2003.
3. G.K. Dubey, *Thyristorised Power Controllers*, Wiley Eastern Ltd., 2005.
4. Dewan & Straughen, *Power Semiconductor Circuits*, John Wiley & Sons, 1975.
5. M.D. Singh & K.B. Khanchandan, *Power Electronics*, Tata McGraw Hill, 2007.
6. B. K Bose, *Modern Power Electronics and AC Drives*, Pearson Education (Asia), 2015.

EE6302E DYNAMICS OF ELECTRICAL MACHINES

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Formulate electrodynamic equations for the electrical machines.
CO2: Analyse the performance of the electrical machines using the electrodynamic equations.
CO3: Develop power invariant transformations for the dynamic analysis of electrical machines.
CO4: Perform stability analysis of the electrical machines under small signal and transient conditions.

Primitive Machine Concept and Analysis of DC Machines
Electrodynamic equations and their solution - a spring and plunger system - rotational motion system - mutually coupled coils - Lagrange's equation - application of Lagrange's equation to electromechanical systems - solution of electrodynamic equations by Euler's and Runge-Kutta methods - Linearisation of the dynamic equations and the small signal stability - differential equations and solutions - a smooth air-gap two winding machine - a two phase machine with current excitation - interpretation of the average power conversion conditions in terms of air-gap magnetic fields - primitive 4 winding commutator machine - commutator primitive machine - brush axis and its significance - self and mutually induced voltages in the stationary and commutator windings - speed emf induced in commutator winding - rotational inductance coefficients - sign of speed emf terms in the voltage equation - complete voltage equation of primitive 4 winding commutator machine - torque equation - analysis of dc machine using the primitive machine equations.

Analysis of Induction Machines
Three phase induction motor - equivalent two phase machine by mmf equivalence - equivalent two phase machine currents from three phase machine currents - power invariant phase transformation - voltage transformation - voltage and torque equations of the equivalent two phase machine - commutator transformation and its interpretation - transformed equations - different reference frames for induction motor analysis - nonlinearities in machine equations - equations under steady state - linearised equations of induction machine - small signal and transient stability analysis - eigen values - transfer function formulation-dependence of motor inductances on various parameters and geometry

Analysis of Synchronous Machines
Three phase salient pole synchronous machine - voltage and torque equations in various reference frames - commutator transformation and transformed equations - parks transformation - suitability of reference frame - steady state analysis - large signal transient analysis - eigen values - general equations for small oscillations - small oscillation equations in state variable form - damping and synchronizing torques - small oscillation stability analysis - modeling of Permanent Magnet Synchronous Motor (PMSM).

Analysis of Interconnected Machines
Dynamic analysis of interconnected machines - machine interconnection matrices - transformation of voltage and torque equations using interconnection matrices - large signal transient analysis using transformed equations - small signal model using transformed equations - dc generator-motor system - synchronous generator-motor system - hunting analysis of interconnected machines - selection of proper reference frame for individual machines in an interconnected system.

References:

1. D P Sengupta & J.B. Lynn, *Electrical Machine Dynamics*, The Macmillan Press Ltd., 1980.
2. R Krishnan, *Electric Motor Drives, Modeling, Analysis and Control*, Pearson Education, 2001.
3. P.C. Kraus, *Analysis of Electrical Machines*, McGraw Hill Book Company,1987.
4. Boldia & S A Nasar, *Electrical Machine Dynamics*, The Macmillan Press Ltd., 1992.
5. C.V. Jones, 'The Unified Theory of Electrical Machines', Butterworth, London., 1967.
6. D.W. Novotny and T.A. Lipo, *Vector Control and Dynamics of AC Drives*, Oxford Science Publications, 1996.
7. Duane Hanselman , *Brushless Motors: Magnetic Design, Performance, and Control of Brushless DC and Permanent Magnet Synchronous Motors*, Magna Physics Publishing, 2012.
8. Enamul Md Haque, *Permanent Magnet Synchronous Motor Drives: Analysis, Modeling and Control*, VDM Verlag, 2009.

EE6303E MODERN DIGITAL SIGNAL PROCESSORS

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand and analyse the architecture of digital signal processors.
CO2: Design a digital system using digital signal processors
CO3: Program various DSP processors using IDEs.
CO4: Choose and utilize modern digital signal processors for power electronic applications.

Introduction to Digital Signal Processors (DSP)

Types of digital processors- microprocessor, microcontroller, digital signal processors/controllers, differences in architecture, features, peripherals and functionality, Memory hierarchy, types of memory, memory map, Instruction set.

Modern trends in DSP: Von Newmann versus Harvard architecture, fixed- and floating-point processors, New Digital Signal Processing hardware trends, Selection of DS processors.

Internal details of DSP using Texas Instruments DSP (TMS330C6000 Series) as a tool: DSP Architecture, CPU Data Paths and Control, Internal Data/Program Memory. On chip peripherals and its programming details: Timers - Multi channel buffered serial ports - Extended Direct Memory Access, Interrupts, Pipelining.

Programming the DSP

Texas Instruments IDE - CC Studio - Introduction to the C6713 DSK- Review of FIR filtering: FIR filter designtechniques and tools, Review of IIR filtering: IIR filter design techniques and tools, Sampling, quantization andworking with the AIC23 codec, Writing efficient code: optimizing compiler - effect of data types and memory map. TMS320C6713 Assembly language Programming: Instructions Set and Addressing Modes – Linear Assembly. Interfacing CC Studio with MATLAB.

Current Trend in Digital Signal Processors

Converter and Motor Control Digital Signal Processing Solutions Using the TMS320F240DSP-Controller. Architecture of TMS320C2XX series DSP and its applications. Architecture trends of other DSP processors, Analog Devices DS processors: ADSP-2105 digital signal processor for motor control applications, Microchip dsPIC controllers for power electronics applications. Other major vendors in the DSP market and the latest trends.

References:

1. On-line TI materials for the TI C6713 DSK board: http://www.ti.com
2. Naim Dahnoun, *Digital Signal Processing Implementation using the TMS320C6000 DSP Platform*, 1st Edition.
3. R. Chassaing, *Digital Signal Processing and Applications with the C6713 and C6416 DSK*, John Wiley and Sons, Inc., New York, 2004
4. Sen M. Kuo and Woon-Seng Gan., *Digital Signal Processors: Architectures, Implementations, and Applications*, Pearson, 2005.
5. David J Defatta J, Lucas Joseph G & Hodkiss William S, *Digital Signal Processing: A System Design Approach*, 1st Edition; John Wiley, 2009.
6. A.V. Oppenheim and R.W. Schafer, *Discrete-Time Signal Processing*, Third Edition, Pearson, 2014.
7. John G Proakis, Dimitris G Manolakis, *Digital Signal Processing*, Pearson, 2006.
8. On-line Microchip materials: http://www.microchip.com/design-centers/intelligent-power

EE6391E POWER ELECTRONICS LAB

Pre-requisites: **NIL**

L	T	P	O	C
0	0	2	1	1

Total Practical Sessions: 26

Course Outcomes:

CO1: Determine the characteristics of various semiconductor switches used in power electronic converters.
CO2: Design, develop and test uncontrolled /controlled rectifiers, dc-dc converters and inverters.
CO3: Analyse and evaluate the performance of power converters using latest measurement/test equipment.
CO4: Prepare a detailed report on the experimental work, its results and inferences.

List of Experiments:

1. To study static characteristics of SCR, TRIAC, MOSFET and IGBT and measure latching and holding currents of an SCR.
2. To study single-phase half wave, Full wave, Controlled rectifier with (i) resistive load (ii) inductive load with and without freewheeling diode. Use UJT trigger circuit to trigger the SCRs.
3. Modeling and Simulation of Buck, Boost and Buck-Boost Converters.
4. Study of Basic Buck Converter (HW).
5. Study of Basic Boost Converter (HW).
6. Modeling and Simulation of Isolated DC/DC Converters (Flyback & Forward Converters).
7. Study of Phase Controlled Rectifiers and PWM Rectifiers.
8. Study of Single-Phase Inverters and Modulation Techniques. Use any microcontroller to generate the required pulses to control the inverter.
9. Study of 3-Phase Inverters and Modulation Techniques (Simulation).
10. Study of Multilevel Inverters and their Modulation Techniques.
11. Study of matrix converter and its control.
12. Speed control of a separately excited D.C. Motor using an IGBT or MOSFET chopper.

References:

1. M D Singh, K B Kanchandhani, *Power Electronics*, Tata Mc Graw Hill Publishing Company, 2nd Edition, 1998.
2. G K Dubey, S R Doradra, A Joshi, R M K Sinha, *Thyristorised Power Controllers*, New Age International Limited, 2nd Edition, 2008.
3. Dr. P S Bimbhra, *Power Electronics*, Khanna Publishers, 5th Edition, 2012.
4. M H Rashid, *Power Electronics, Circuits, Devices and Applications*, Pearson, 3rd Edition, 2001.
5. Vedam Subramanyam, *Power Electronics*, New Age International Limited, 2nd Edition, 2006.
6. P C Sen, *Power Electronics*, Tata McGraw-Hill Publishing, 1st Edition, 1987.
7. V R Moorthi, *Power Electronics Devices*, Oxford University Press, 4th Edition, 2005.
8. Ned Mohan, Tore M Undeland, William P Robbins, *Power Electronics: Converters, Applications and Design*, 3rd Edition, John Wiley and Sons, 2002.

EE6311E POWER ELECTRONIC CIRCUITS - II

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

CO1: Analyse and design Load Commutated CSI and PWM CSI.
CO2: Demonstrate the working of series inverters.
CO3: Select Switched Mode Rectifiers and APFC topologies for any given application.
CO4: Explain the operation and control of resonant mode converters.

High Power Converters

Multi-Level Inverters of Diode Clamped Type and Flying Capacitor Type and suitable modulation strategies -Cascade Type Multi-level inverters
Special Inverter Topologies - Current Source Inverter. Ideal Single Phase CSI operation, analysis andwaveforms - Analysis of Single Phase Capacitor Commutated CSI.
Series Inverters. Analysis of Series Inverters. Modified Series Inverter. Three Phase Series Inverter

Switched Mode Rectifiers and Power Factor Correction Converters

DC-DC converters – Design of DC-DC converter for PFC. Design of voltage loop and current loop.

Switched Mode Rectifier: Operation of Single/Three Phase bilateral Bridges in Rectifier Mode. Control Principles. Control of the DC Side Voltage. Voltage Control Loop. The inner Current Control Loop. Single phase and three phase boost type APFC and control, Three phase utility interfaces and control

Single Phase and 3 Phase Boost type APFC - DCM, BCM, CCM design and control strategies, Single Phaseand 3 Phase bidirectional converters in rectifier mode - control of DC voltage - control of Input Current.
Hysteresis control in Single Phase and three Phase rectifiers- Frequency control in hysteresis, Constant switching frequency control methods.

Resonant Converters

Introduction to Resonant Converters. Classification of Resonant Converters. Basic Resonant Circuit Concepts. Load Resonant Converter. Resonant Switch Converter. Zero Voltage Switching Clamped Voltage Topologies.Resonant DC Link Inverters with Zero Voltage Switching. High Frequency Link Integral Half Cycle Converter.Resonant converters for induction heating.
Introduction to Dual active bridge dc-dc converter- Phase angle control for power transfer, application of DAB for battery chargers.

References:

1. Ned Mohan, *Power Electronics: Converters, Applications, and Design*” John Wiley and Sons, 2006.
2. Bin Wu, *High-Power Converters and AC Drives*, IEEE Press, A John Wiley & Sons, Inc., Publication, 2017.
3. Rashid, *Power Electronics*, Prentice Hall India, 2007.
4. G.K. Dubey, *Thyristorised Power Controllers*, New Age Publishers, 2012.
5. Dewan & Straughen, *Power Semiconductor Circuits*, John Wiley & Sons., 1975.
6. G.K. Dubey & C.R. Kasaravada, *Power Electronics & Drives*, Tata McGraw Hill., 1993.
7. IETE Press Book, *Power Electronics*, Tata McGraw Hill, 2003.
8. Cyril W Lander, *Power Electronics*, McGraw Hill., 2005.
9. B. K Bose, *Modern Power Electronics and AC Drives*, Pearson Education (Asia)., 2007
10. Abraham I Pressman, *Switching Power Supply Design*, McGraw Hill Publishing Company, 2001.
11. 11.Daniel M Mitchel, *DC-DC Switching Regulator Analysis*, McGraw Hill Publishing Company, 1988.

EE6312E POWER ELECTRONIC DRIVES

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Choose a suitable Motor and Power Electronic Converter system from a description of drive requirement - involving load estimation, load cycle considerations, thermal aspects and motor-converter matching.
CO2: Design various DC and AC drives.
CO3: Demonstrate Electrical Motor operation using generalized machine theory.
CO4: Explain the working and design of various converters used in Electrical Drives

Analysis of DC Motor Drives

Introduction to Motor Drives - Components of Power Electronic Drives – Criteria for selection of Drive components - Match between the motor and the load - Thermal consideration- Characteristics of mechanical systems - stability criteria, D.C Motor Drives - System model motor rating - Motor-mechanism dynamics - Drive transfer function –Drives control-speed controller design-Current Controller design-Effect of armature current waveform - Torque pulsations –Adjustable speed dc drives - Effect of field weakening

Induction Motor Drives

Induction Motor Drives - Basic Principle of operation of 3 phase motor – Equivalent Circuit, Space harmonics due to fundamental current - Fundamental spatial mmf distributions due to time harmonics -Simultaneous effect of time and space harmonics - Speed control by varying stator frequency and voltage (scalar control)- Impact of non-sinusoidal excitation on induction motors - Variable frequency converter classifications -Variable frequency PWM-VSI drives - Variable frequency square wave VSI drives - Variable frequency CSI drives - Comparison of variable frequency drives - Speed control by static slip power recovery.

Vector Control of Induction Motors

Speed control of 3 phase squirrel cage motors – Principle of vector control, Direct Torque Control-Space Vector Modulation Based, Field orient control-Direct and Indirect, Design of a FOC control loop with SPWM and SVM, Introduction to Sensorless Control- challenges

Analysis of Synchronous Motor Drives
Synchronous Motor Drives - Introduction - Basic principles of synchronous motor operation methods of control - operation with field weakening - load commutated inverter drives. PMSM Drives, Switched reluctance motor drives, BLDC motor drives

References:

1. Ned Mohan, *Power Electronics*, Wiley, 2006
2. R Krishnan, *Electric Motor Drives*, *Modeling, Analysis, and Control*, Pearson Education, 2001.
3. G.K. Dubey & C.R. Kasaravada, *Power Electronics & Drives*, Tata McGraw Hill,1993.
4. W.Shephered, L N Hulley Cambride, *Power Electronics & Control of Motor*, University Press, 2005.
5. Dubey, *Power Electronics Drives*, Wiley Eastern,1993.
6. Chilikin M, *Electric Drives*, Mir publications, 2nd edition,1978.
7. Enamul Md Haque , *Permanent Magnet Synchronous Motor Drives: Analysis, Modeling and Control*, 2009.
8. T.J.E Miller, *Brushless permanent Magnet & Reluctance Motor Drives*, Clarendom Press, Oxford 1989.
9. Kenjo T and Nagamoris, *Permanent Magnet & brushless Dc motor*, Clarendon press, Oxford, 1989.

EE6313E DIGITAL CONTROL OF POWER ELECTRONIC CONVERTERS

Pre-requisites: **NIL**

L	T	P	O	C
2	0	2	5	3

Total Sessions: 26L + 26P

Course Outcomes:

CO1: Explain the structure of the digital control loop as well as the various functionalities of modern DSP processors.
CO2: Model and analyse various elements in the digital control loop of a power converter.
CO3: Design and realize digital compensators in z-domain from their s-domain transfer function considering the practical implementation aspects
CO4: Implement, test and debug realizations of digital compensators and modulation techniques in advanced digital processors.

Lecture Sessions:

Introduction to Digital Control of Power Converters
Digital Control Loop- Control Loop structure, Comparison with analog control loop, Analog to Digital Conversion, Sampling Rate, Aliasing effect, Digital Compensator, Digital Pulse Width Modulator, Sensors.

Overview of various digital signal processors for power electronic applications- Introduction to TMS320F28379D processor-Architecture, GPIO, Timers, Interrupts, ADC module, PWM module, HRPWM, eCAP module, eQEP module.

Modeling of Various Elements in the Digital Control Loop
Revision of bode plots and stability criteria in frequency domain.
Brief discussion on power converter modeling, small signal model of power converter, s-domain transfer functions, design of an analog compensator in s-domain.
Amplitude quantization of ADC and DPWM, resolution and limit-cycling effect, No limit-cycling conditions, ADC and DPWM modeling in time domain and s-domain
Different types of modulators: leading edge and trailing edge modulation - non-linear effects of various modulators, Time domain and s-domain model of modulators.
Sensors- sensor gain, delays, non-linear effects.
Various delays in digital implementation- sampling delays, computational delays, PWM delay. Modeling of delays- Pade approximation- Effect of delays on loop gain transfer function- Phase margin reduction and instability due to delays.
Design of s-domain transfer function of the compensator in a digital control loop- Comparison between compensators in digital implementation and analog implementation using bode plots.

Digital Realization of Compensators
Revision- z-transforms, z-transform identities.
Significance of z-transform in digital control- continuous to discrete domain transformation using Euler methods (Forward Euler and Backward Euler) and Bilinear transformation- Comparison between transformation methods- Analysis of s-domain and z-domain compensator transfer functions using Bode plots- Significance of Nyquist Frequency- Pre-warping techniques-Comparison of compensator bode plots for different sampling times- Difference equations and their realization.

Digital Implementation Aspects
Selection of digital processor for a given power converter application- Digital voltage mode control of a buck converter-SPWM and SVM of a three-phase inverter -Digital control simulation in MATLAB and comparison with analog based control- Choice of step size and solvers in simulations
Case study: Digital realization of Sine PWM in a digital processor using look-up table and floating-point unit-Implementation of Space Vector Modulation using a digital processor

Practical Sessions:

List of Experiments
1. Familiarization with F28379D launchpad and CC Studio software
2. Mathematical operation on numbers and matrices using F28379D

3. Generation of PWM pulses using Timers and Interrupts modules of F28379D
4. Generation of PWM waveforms using F28379D PWM module
5. Configuration of ADC module in F28379D and simultaneous sampling of signals
6. PWM duty cycle control using ADC module of F28379D
7. Implementation of a digital compensator in F28379D
8. Sine PWM implementation using F28379D
9. Digital compensator implementation using F28379D
10. PWM generation with dead time using F28379D

References:

1. Luca Corradini, Dragan Maksimovic, Paolo Mattavelli, Regan Zane, *Digital Control of High-Frequency Switched-Mode Power Converters*, Wiley-IEEE Press, 2015.
2. Simone Buso, Paolo Mattavelli, *Digital Control in Power Electronics*, Morgan and Claypool Life Sciences, 2015.
3. Robert W. Erickson and Dragan Maksimovic, *Fundamentals of Power Electronics*, Springer, 2001.
4. TMS320F28379D datasheet, Texas Instruments website.

EE6314E SWITCHED MODE POWER CONVERSION

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the principles of operation of non-isolated and isolated hard-switched DC-DC converters
CO2: Illustrate various loss components in a switched mode converter and choice of switching frequency witha view towards design of such converters
CO3: Demonstrate the magnetics in switched mode converters and design of high frequency inductors andtransformers with a DC bias.
CO4: Design voltage mode and current mode control of DC-DC converters and familiarization with variouscontroller ICs available in the market.
CO5 Develop large-signal model and small signal model of hard-switched converters, develop the transferfunctions and design error amplifiers in the feedback loop.
CO6: Analyse the transients and their control in hard-switched converters by use of proper wiring practices,judicious component selection and various snubbers.

Non-Isolated DC to DC Converters
Linear Regulation versus Switched Mode Regulation- Basic DC-DC Converter Structures and Two Basic Principles for steady-state analysis of DC-DC Converters.

Buck, Boost, Buck-Boost SMPS Topologies - Basic Operation - Waveforms - Modes of operation CCM, DCM and BCM – Ideal Waveforms and relations in all three modes – Effect of switch resistance, diode cut-in voltage, diode resistance, series resistance of inductor, ESR of capacitor etc. on input-output relation of these converters. Voltage Mode Control Principles.

Analysis of Switching in a Buck Converter (use MOSFET as the switching device for this topic) - switching stresses - Reverse recovery of diodes - Switch-ON time and Switch-OFF time- switching and conduction losses.

Switch-OFF Snubber and Switch-ON Snubber for MOSFET/IGBT based SMPS Units – Selection of Snubber component size and impact of parasitic inductances on snubber component values - choice of switching frequency in a given converter design problem.

Gating Circuits for MOSFETs and IGBTs – Requirement for Level Shifting and/or Isolation – Pulse Transformer Isolated Gate Driver Circuits – Opto-Isolated Gate Drivers – Level Shifting Gate Drivers

Isolated DC to DC Converter Topologies
Need for & advantages of employing a high frequency isolation transformer in SMPS designs – Single-ended Forward Converter – need for tertiary winding – effect of leakage inductance on input-output relation of Forward Converter – Double-ended Forward Converter

Push-Pull DC-DC Converter – Flux Walking Problem and Solution – Effect of leakage inductance on input-output relation.

Half-Bridge DC-DC Converter – Waveforms, Relations, Component Stresses in CCM mode – Selection of Voltage Splitting Capacitors – Flux Walking problem and solution. Full-Bridge DC-DC Converter- Flyback Converter in DCM and CCM – Waveforms and Design Relations for DCM and CCM Designs – Effect of Leakage inductance - Passive Voltage Clamp Design

Design of Magnetics
Ferrite material and its magnetic properties – Ferrite Cores – A_c , A_w , A_L and area product of ferrite cores of various shapes – Design of Inductors with DC Current Bias using air-gapped Ferrite Cores – Output equation of various isolated converters – Design of high-frequency transformers using Ferrite cores – core selection – winding calculations – winding layout – use of litz wire and foil windings - estimation of core loss in Inductor and Transformer designs – Copper loss in Inductors and transformers – Skin effect and Proximity effect – Use of Dowell's curves for copper loss estimation. Current Transformers for sensing switched currents and their design using Toroidal ferrite cores.

Modeling & Control of SMPS Units

Small-signal Modeling of Converters for Control Design -The switching function – Switched model of a DC-DC Converter – Local Average of variables in a fixed-frequency Switched Mode Converter- The duty-ratio function versus duty-ratio – Local Average Model for a Switched Mode Converter – State Space Average Model (which is an approximate version of local average model) – Solving for steady-state behavior from SSA Model – Linearised SSA Model and Small Signal Transfer Functions for Buck & Boost Converters – Effect of operating point and ESR of Capacitor on small signal transfer functions, the RHP zero in Boost Converter model

Design of Type-I, Type-2 and Type-3 Compensators for Voltage Mode Control of SMPS based on small-signal transfer functions – Realization of these compensators using Opamps and Transconductance Amplifiers – Study of SG3525 VMC PWM Control IC

Current Mode Control – Advantages – Subharmonic Instability – Slope Compensation – Ideal Slope for Slope Compensation – Design of Outer Voltage Control Loop in Current Mode Controlled Converter – Study of UC3842 CMC PWM Control IC

Principles of One Cycle Control as applied to DC-DC Converters

EMI Generation and Filtering in SMPS - Conducted and Radiated Emission Mechanisms in SMPS. Techniques to reduce emissions, Shielding and Grounding- Power Circuit Layout considerations for reducing EMI. EMI Filtering at Input and Output- Effect of Input side EMI Filter on SMPS Control Dynamics.

References:

1. Abraham I Pressman, *Switching Power Supply Design*, McGraw Hill Publishing Company, 2001.
2. Robert W. Erickson and Dragan Maksimovic, *Fundamentals of Power Electronics*, Springer, 2001.
3. Daniel M Mitchell, *DC-DC Switching Regulator Analysis*, McGraw Hill Publishing Company-1988
4. Ned Mohan, *Power Electronics*, John Wiley and Sons 2006
5. Keith H Billings, *Handbook of Switched Mode Power Supplies*, McGraw Hill Publishing Company,1989.
6. Mark J Nave, *Power Line Filter Design for Switched-Mode Power Supplies*, VanNostrand Reinhold, New York, 1991

EE6392E SEMINAR

Pre-requisites: **NIL**

L	T	P	O	C
0	0	2	1	1

Course Outcomes:

CO1: Summarize the objective of a research paper related to the field of power electronics and critically review the effectiveness of the work

CO2: Identify promising new directions of various cutting-edge technologies

CO3: Prepare a detailed report describing the reviewed topic

CO4: Communicate effectively through oral presentations

Each student will be asked to choose a topic in any field of Power Electronics, preferably from outside the M.Tech syllabus and give seminar on the topic for about thirty minutes. The student has to present a critical review of the research paper and its relevant references in the seminar. A committee specialized on different fields of power electronics will assess the presentation of the seminars and award the marks to the students.

EE6393E PROJECT PHASE I

Pre-requisites: **NIL**

L	T	P	O	C
0	0	3	3	2

Course Outcomes:

CO1: Develop a complete design of a simple power electronic converter, implement the hardware prototype/experimental setup and obtain the experimental results.

CO2: Formulate detailed design reports describing the relevance of the project, modelling aspects, methodologies and analysis of the results

CO3: Communicate effectively through oral presentations

The Project Phase I can be a small design and fabrication project in any of the areas in Power Electronics. Project must be done by each student as an individual work. This project is allotted by the Department at the beginning of 2nd semester and shall be completed before the end of 2nd semester.

EE7391E PROJECT PHASE II

Pre-requisites: **NIL**

L	T	P	O	C
0	0	6	3	3

Course Outcomes:

CO1: Identify a research project topic from the latest power electronic technologies

CO2: Perform literature survey and analysis of latest converter topologies and their control techniques.

CO3: Formulate a detailed design report describing the relevance of the project

CO4: Communicate effectively through oral presentations

The Project Phase II can be an analytical / simulation / design or/and fabrication project in any of the areas in Power Electronics. This project can also be a preliminary work for the Project Phase III and IV. This project must be done by individual student in the Electrical Engineering Department. This project is to be completed during the summer vacation period after the 2nd semester. The student has to submit a detailed report and give an oral presentation to the evaluation panel.

EE7392E PROJECT PHASE III

Pre-requisites: **NIL**

L	T	P	O	C
0	0	30	15	15

Course Outcomes:
CO1: Design and analyse complex power electronic circuits / systems.
CO2: Perform the preliminary work of undertaking case studies, data collection and feasibility studies.
CO3: Prepare a power converter design proposal and effectively document the same.
CO4: Communicate effectively through oral presentations on the progress of work.

The project work will be a design project / simulation/experimental project in the areas of Power Electronics to be done by each individual student. The assessment of the project will be done by a committee specialized in various fields of power electronics. The students will present their project work before the committee through oral presentations. A 30-40 page typed report based on the work done will have to be submitted by the students to the evaluation committee.

EE7393E PROJECT PHASE IV

Pre-requisites: NIL

L	T	P	O	C
0	0	30	15	15

Course Outcomes:

CO1: Develop comprehensive solution to issues identified in the preliminary work and to meet the requirements as stated in the project proposal.

CO2: Validate experimentally the detailed analytical/simulation studies conducted, lay down validity and design criteria and interpret the results to achieve the objectives.

CO3: Report the concept, detailed design solutions and results

CO4: Communicate effectively the thesis rationale and publish in reputed journals/conferences

The project work will be an experimental project in the areas of Power Electronics done by each individual student. Evaluation will be done by a project evaluation committee. The mode of presentation, submission of the report, method of evaluation, award of grades etc will be decided by the evaluation committee. Students shall give oral presentations and submit a detailed report as per the guidelines of the Department. Students are expected to publish their research contributions in reputed conferences and/or journals.

EE6321E POWER SEMICONDUCTOR DEVICES AND MODELING

Pre-requisite: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the basics of power semiconductor switches.
CO2: Illustrate the working of various types of converters and application of them.
CO3: Design the drive circuits for various power semiconductor switches.
CO4: Model the converters and semiconductor switches.
CO5: Design the control of various power semiconductor switches.

Diodes and Thyristors

Power Diodes. Basic Structure and I-V Characteristics. Breakdown Voltages and Control. On State Losses. Switching Characteristics. Turn on Transient. Turn off Transient. Reverse Recovery Transient. Schottky Diodes. Snubber Requirements for Diodes and Diode Snubbers. Thyristors - Basic Structure. V-I Characteristics. Turn on Process. On State operation. Turn off process

Switching Characteristics. Turn on Transient and di/dt limitations. Turn off Transient. Turn off time and reapplied dv/dt limitations. Ratings of Thyristors. Snubber Requirements and Snubber Design. Triacs . Basic Structure and operation. V-I Characteristics. Ratings. Snubber Requirements.

Gate Turnoff Thyristor (GTO). Basic Structure and Operation. GTO Switching Characteristics. GTO Turn on Transient. GTO Turn off Transient. Minimum ON and OFF State times. Maximum Controllable Anode Current.Over current protection of GTOs

Power BJTs, MOSFETs and IGBTs

Power BJTs. Basic Structure and I-V Characteristics. Breakdown Voltages and Control. Second Breakdown and its

Control- FBSOA and RBSOA Curves - On State Losses. SwitchingCharacteristics.

Resistive Switching Specifications. Clamped Inductive Switching Specifications. Turn on Transient. Turnoff Transient. Storage Time. Base Drive Requirements. Switching Losses. Device Protection-Snubber.Requirements for BJTs and Snubber Design - Switching Aids.

Power MOSFETs - Basic Structure. V-I Characteristics. Turn on Process. On State operation. Turn off process, Switching Characteristics. Resistive Switching Specifications. Clamped Inductive Switching Specifications - Turn on Transient and di/dt limitations. Turn off Transient. Turn off time. Switching Losses.Effect of Reverse Recovery Transients on Switching Stresses and Losses - dv/dt limitations.

Gating Requirements. Gate Charge - Ratings of MOSFETs. FBSOA and RBSOA Curves. Device Protection –Snubber Requirements.

Insulated Gate Bipolar Transistors (IGBTs). Basic Structure and Operation. Latch up IGBT Switching Characteristics. Resistive Switching Specifications. Clamped Inductive Switching Specifications – IGBT Turnon Transient. IGBT Turn off Transient- Current Tailing - Ratings of MOSFETs. FBSOA and RBSOA Curves. Switching Losses - Minimum ON and OFF State times - Switching Frequency Capability – Over current protection of IGBT. Short Circuit Protection. Snubber Requirements and Snubber Design.

New power semiconductor devices. Thermal design of power electronic equipment. Modeling of power semiconductors (principles). Simulation tools

Modeling of Semiconductor Devices

Gating Requirements for Thyristor, Component Temperature Control and Heat Sinks. Control of device temperature. heat transfer by conduction. transient thermal impedance - heat sinks. heat transfer by radiationand convection - Heat Sink Selection for SCRs and GTOs.

Modeling of power diode - Modeling of power MOSFET - Modeling of bipolar transistor - Modeling of IGBT

Wide band gap devices – Modeling and driver design of SiC, GaN devices.

References:

1. Ned Mohan, *Power Electronics*, John Wiley and Sons, 2006.
2. G. Massobrio, P. Antognet, *Semiconductor Device Modeling with Spice*, McGraw-Hill, Inc.,1988.
3. B. J. Baliga, *Power Semiconductor Devices*, Thomson, 2004.
4. V. Benda, J. Gowar, D. A. Grant, *Power Semiconductor Devices. Theory and Applications*, John Wiley & Sons,1998.

EE6322E STATIC VAR CONTROLLERS AND HARMONIC FILTERING

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Explain about the different power quality issues in Power Grid
CO2: Design and analyse the three phase and single-phase static power compensators in Transmission and Distribution level in Power Systems.
CO3: Design and analyse the converter based static compensators in Power Systems.
CO4: Analyze and model Active Harmonic Filtering systems with a vision towards its Controller Design

Fundamentals of Power Quality

Power Quality Issues. Sags, Swells, Unbalance, Flicker, Distortion, Current Harmonics - Sources of Harmonics in Distribution Systems and its Effects.
Fundamentals of Load Compensation, Steady-State and Dynamic Reactive Power Control in Electric Transmission and Distribution Systems,

Thyristor based Compensators

Static Reactive Power Compensators and their control. Shunt Compensators, SVCs of Thyristor Switched and Thyristor Controlled types and their control, STATCOMs and their control, Series Compensators of Thyristor Switched and Controlled Type and their Control, SSSC and its Control, Sub-Synchronous Resonance and damping, Use of STATCOMs and SSSCs for Transient and Dynamic Stability Improvement in Power Systems.

Converters for Static Compensation

Converters for Static Compensation. Single Phase and Three Phase Converters and Standard Modulation Strategies (Programmed Harmonic Elimination and SPWM). GTO Inverters. Multi-Pulse Converters and Interface Magnetics. Multi-Level Inverters-Flying Capacitor Type and suitable modulation strategies for reactive power compensation, Current Control of Inverters.

Series and Shunt Active Filters
Passive Harmonic Filtering. Single Phase Shunt Current Injection Type Filter and its Control, Three Phase Three-wire Shunt Active Filtering and their control using p-q theory and d-q modelling. Three-phase four wire shunt active filters. Hybrid Filtering using Shunt Active Filters. Series Active Filtering in Harmonic Cancellation Mode. Series Active Filtering in Harmonic Isolation Mode. Dynamic Voltage Restorer and its control. Power Quality Conditioner

References:

1. J.E Miller, *Reactive Power Control in Electric Systems*, John Wiley & Sons,1982.
2. N.G. Hingorani & L. Gyugyi, *Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems*, IEEE Press, 2000.
3. Ned Mohan, *Power Electronics*, John Wiley and Sons, 2006.
4. R. Sastry Vedam & Mulukutla S. Sarma, *Power Quality: VAR Compensation in Power Systems*, CRC Press, 2009.
5. Miller, *Reactive Power Compensation in Electric System*, Wiley Publication, 2010.
6. Deare A Paice, *Power Electronics Converter Harmonics*, IEEE Press, 1999.
7. C. Sankaran, *Power Quality*, CRC Press, 2002.

EE6323E DIGITAL SIMULATION OF POWER ELECTRONIC SYSTEMS

Pre-requisite: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Develop mathematical model of power electronic switches and electrical machines.
CO2: Model and simulate Power Electronic Systems using software packages such as PSpice, MATLAB-Simulink & Saber
CO3: Design and simulate power electronic systems using PSpice.
CO4: Illustrate power electronic system design and simulation using MATLAB-Simulink.
CO5: Analyse and design power electronic systems and simulate using Saber

Principles of Modelling Power Semiconductor Devices

Macro models versus Micro models– Semiconductor device models - Semiconductor Device modelled as Resistance, Resistance-Inductance and Inductance-Resistance-Capacitance combination - Modelling of Electrical Machines - Modelling of Control Circuits for Power Electronic Switches. Computer Formulation of Equations of Power Electronic Systems - Review of Graph Theory as applied to Electrical Networks - Systematic method of Formulating State. Equations – Computer Solution of State Equations - Explicit Integration method - Implicit Integration method.

Simulation with MATLAB

Overview of MATLAB Workspace, Simulink and Simscape- Writing a code in MATLAB Editor- Various solvers and simulation step size in simulations- Circuit simulation of a power converter using Simulink- Model based simulation of a power converter system using Simulink-Coding the MATLAB function block.

Simulation with PSpice

Circuit Analysis Software MicroSim PSpice A/D - Simulation Overview - Creating and Preparing a Circuit for Simulation - Simulating a Circuit with PSpice A/D - Displaying Simulation Results - PSpice A/D Analyses-Simple Multi-run Analyses - Statistical Analyses - Simulation Examples of Power Electronic systems.

Simulation with Saber

Design Creation and Simulation with Saber Designer - Placing the Parts - Editing the Symbol – Properties -Wiring the Schematic - Modifying Wire Attributes - Performing a Transient and DC Analysis – Placing Probes in the Design - Performing AC Analysis and Invoking Saber Scope - Analysing waveforms with Saber Scope - Performing Measurements on a waveform - Varying a Parameter - Displaying the Parameter Sweep Results - Measuring a Multi-Member Waveform - Simulation Examples of Power Electronic Systems.

References:

1. V.Rajagopalan, *Computer Aided Analysis of Power Electronic Systems,* Marcel Dekker, Inc,1987.
2. *Micro Sim PSpice A/D and Basics+: Circuit Analysis Software*, User's Guide, Micro Sim Corporation
3. *Micro Sim Schematics: Schematic Capture Software*, User's Guide, Micro Sim Corporation.
4. Farzin Asadi, *Simulation of Power Electronics Circuits with MATLAB/Simulink: Design, Analyze, and Prototype Power Electronics*, Apress, 2022.
5. *Getting Started with Saber Designer (Release 5.1),* An Analogy Inc.

EE6324E ADVANCED CONTROL OF INVERTER-FED INDUCTION MOTOR DRIVES

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Illustrate the dynamic model of induction machines for different frames of reference.
CO2: Design field oriented (vector) control system of induction machines.
CO3: Analyze the effects of machine parameter variations on the performance of induction machine feddrives.
CO4: Explain the sensor-less speed control methods of induction machines.
CO5: Design a vector controlled induction machine drive system

Introduction and Induction Machine Dynamic Model

Principles for vector and field-oriented control-Complex-valued dq-model of induction machines. Turns ratio and modified dq-models. Principles for field-oriented vector control of ac machines. Current controllers in stationary and synchronous coordinates. Rotor-flux oriented control of current-regulated induction machine - Dynamic model of IM in rotor-flux coordinates. Indirect rotor-flux orientedcontrol of IM - Direct rotor-flux oriented control of IM.-Methods to estimation of rotor-flux

Vector Control Techniques

Generalized flux-vector control using current- and voltage decoupling networks- Generalized flux-vector oriented control. Current and voltage decoupling networks. Air gap-oriented control. Voltage-fed vector control. Stator-flux oriented vector control.

Effect of Parameter Variations on Performance

Parameter sensitivity, selection of flux level, and field weakening - Parameter detuning in steady-state operation. Parameter detuning during dynamics. Selection of flux level. Control strategies for used in the over-speed region.

Sensorless Speed Control

Principles for speed sensor-less control - Principles for speed sensor-less control. Sensor-less methods forscalar control. Sensor-less methods for vector control. Introduction to observer-based techniques

References:

1. D. W. Novotny and T. A. Lipo, *Vector Control and Dynamics of AC Drives*, Oxford UniversityPress,1996.
2. P. L. Jansen and R. D. Lorenz, *A Physically Insightful Approach to the Design and Accuracy Assessment of Flux Observers for Field Oriented Induction Machine Drives*, IEEE Trans. on IndustryApplications, Vol. 30, No. 1, Jan./Feb. 1994, pp. 101110
3. I. Boldea and S. A. Nasar, *Electric Drives*, CRC Press, 1998.
4. J. Holtz, *Methods for Speed Sensor less Control of AC Drives, in K. Raja shekara Sensor less Controlof AC motors*, IEEE Press Book, 1996. Supplementary literature
5. R. W. De Doncker and D. W. Novotny, *The Universal Field Oriented Controller*, IEEE Trans. on Industry Applications, Vol. 30, No. 1, Jan./Feb. 1994, pp. 92-100.
6. J. Holtz, *The Representation of AC Machine Dynamics by Complex Signal Flow Graphs*, IEEE Transactions on Industrial Electronics, Vol. 42, No. 3, 1995, pp. 263-271

EE6325E LINEAR AND DIGITAL ELECTRONICS

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Demonstrate the operation of BJT and CMOS operational amplifiers with special emphasis on non-ideal effects like offsets, finite impedance levels, finite gain bandwidth product, slew rate, PSRR etc.

CO2: Design various linear applications of opamps, various filters, sinusoidal oscillators etc., to carry outprojects in Power Electronics.

CO3: Analyse and design various nonlinear applications of opamps and comparators such as regenerative comparators, waveform generators, precision rectifiers, log-antilog amps etc.

Op-Amp Circuits and Filters

BJT and MOSFET Differential amplifiers and their analysis, offset behaviour, Current sources for biasing inside a BJT/MOS IC –Properties of ideal Opamps, Internal description of a BJT Opamp, slew rate, internaldescription of a two stage MOS Opamp, Internal description of a Folded Cascode MOS Opamp, Dominantpole compensation – internal and external compensation.

The IOA model of an Opamp, principle of virtual short, offset model for an Opamp, analysis and design ofstandard linear applications of Opamps Reference diodes and voltage references, linear voltage regulators Sinusoidal oscillators using Opamps

Active filtering – Butterworth low pass filter functions - low pass filter specifications - Order and cut off frequency of Butterworth function from low pass specifications –Sallen and Key second order LP section -gain adjustment in Butterworth LP filters –Butterworth high pass filters –

Second order wide band and narrow band band pass filters - multiple feedback single OPAMP LPF, HPF and BPF State variable active filter, Universal active filter.

Waveform Generator Circuits, ADC and DAC

Regenerative Comparators, Comparator ICs, Square-Triangle – ramp generation, sine wave shaping, Function generator ICs , VCO Circuits, VFCs and FVCs and applications, Mono stable and Astable using Opamps, PLL and applications.

Precision rectification, Log and Anti-log amplifiers, IC multipliers, Trans conductance multiplier/divider, Time division multipliers

Analog switches - sample and hold amplifier –Data conversion fundamentals - D/A conversion – weighed resistor DAC - R/2R ladder DAC - current switching DAC - A/D conversion - quantiser characteristics -singleslope and dual slope ADCs - successive approximation ADC - simultaneous ADC

Digital Circuit Basics and Combinational Logic Circuit Design

Basic digital circuits: Review of number systems and Boolean algebra - Simplification of functions usingKarnaugh map - Boolean function implementation. Examples of useful digital circuits:

Arithmetic Circuits, Comparators and parity generators, multiplexers and de multiplexers, decoders andencoders.

Combinational logic design: Combinational circuit design using Multiplexer, ROM, PAL, PLA.

Introduction to Sequential circuits: Latches and flip-flops (RS, JK, D, T and Master Slave) - Design ofaclocked flip-flop – Flip-flop conversion - Practical clocking aspects concerning flip-flops.

Design of Sequential Logic Circuits

Design and analysis of sequential circuits: General model of sequential networks - State diagrams – Analysis and design of Synchronous Sequential Finite Sate Machine – State reduction – Minimization and design of the next state decoder.

Counters: Design of single mode counters and multimode counters – Ripple Counters – Ring Counters –Shift registers counter design.

Practical design aspects: Timing and triggering considerations in the design of synchronous circuits – Setuptime - Hold time – Clock skew.

Asynchronous sequential logic: Analysis and Design – Race conditions and Cycles – Hazards incombinational circuits – Hazard free realization.

References:

1. Sedra & Smith, *Microelectronic Circuits*, Oxford University Press, 2004.
2. Millman J, Microelectronics, McGraw Hill,1999.
3. Anvekar D.K. & Sonde B.S, *Electronic Data Converters*, Tata McGraw Hill,1994.
4. Gayakwad R.A, *OPAMPS & Linear Integrated Circuits*, Prentice Hall of India, 2002.
5. Clayton G.B, *Operational Amplifiers*, ELBS, 2002.
6. Frederiksen T.M, *Intuitive Operational Amplifiers*, McGraw Hill,1988
7. Roth C.H., *Fundamentals of Logic Design*, Jaico Publishers. IV Ed, 2003
8. W. I. Fletcher, *An Engineering Approach to Digital Design*, Prentice-Hall, Inc., Englewood Cliffs,NJ,1980.
9. Tocci, R. J. and Widner, N. S., *Digital Systems - Principles and Applications*, Pearson, 2017.

EE6326E POWER ELECTRONIC DRIVES FOR SPECIAL MACHINES

Prerequisite: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the fundamental principles and classification of servomotor.
CO2: Design the equivalent circuit and evaluate the performance of stepper motor.
CO3: Design the drive amplifier and transistor logic for steppermotor.
CO4: Apply knowledge about the fundamentals, construction details and classification of universal motors and synchronous motor like reluctance motors, hysteresis motors.
CO5: Apply the knowledge of fundamentals, construction details and classification of linear machines.
CO6: Design PMSM and BLDC motor drives

Servo Motors

Servo motors -Requirement of a good servomotor, Types of servomotors: DC servomotor: Basic workingprinciple and its classification, Field controlled and Armature controlled DC servomotor, Application: servo stabilizer and position control system. AC servo motor: construction, operating principle and Application. Symmetrical components applied to two - phase servo motors -equivalent circuit and performance basedon symmetrical components - servo motor torque - speed curves.

Stepper Motors

Stepper motors - construction features - method of operation - drive - amplifiers and transistor logic -DriveCircuits - half stepping and the required switching sequence - the reluctance type stepper motor – ratings.Characteristics of Stepper Motor- Stepper motor application.
BLDC Motor Drive – trapezoidal control- FoC control
PMSM Motor Drive – Operating principle- drive- FoC control of PMSM.

Reluctance motors & Universal motors

Reluctance motors - General types of synchronous motors - Reluctance motors - definitions - construction - polyphase and split phase reluctance motors - capacitor type reluctance motors.

Hysteresis motors - Construction - polyphase - capacitor type and shaded pole hysteresis motors –Methodsof reversing direction of rotation in shaded pole motor. Advantage over reluctance motors, Torque developed and slip
Universal motors – Applications - torque characteristics - essential parts of universal motors - EMF due tomain field and cross field - Transformer and rotational emf - circuit model and Phasor Diagram.

Linear Machines

Linear machines - basic difference between LEMS and rotating - machine – classification of LEMS, linear motors and levitation machines - linear induction motors - linear synchronous motors - DC linear motors –linear levitation machines, edge Effect, MMF wave and its velocity, air gap flux density

References:

1. Toro.V.D, *Electric Machines and Power Systems*, Prentice Hall of India, 1985.
2. Veinott, *Fractional Horsepower Electric Motors*, McGraw-Hill, 1948.
3. Nasar, S.A, Boldea, *Linear Motion Electric Machines*, John Wiley,1976.
4. V.U. Bakshi, U.A. Bakshi, *Electrical Circuits and Machines*, Technical Publication, Pune, 2008.
5. V. V. Athani, *Stepper Motors: Fundamentals Applications and Design*, New Age International 2007.
6. Fitzgerald, Charles Kingsley, Stephen D. Umans, *Electric Machinery*, Tata McGraw-Hill 2002.

EE6327E COMPUTER AIDED DESIGN OF ELECTROMAGNETIC SYSTEMS

Pre-requisites: Fundamental knowledge of electric machine analysis

L	T	P	O	C
2	0	2	5	3

Total Sessions: 26L + 26P

Course Outcomes:

CO1: Understand the basic functioning of the ANSYS user interface
CO2: Choose the simulation settings necessary for a particular problem
CO3: Design and analyse single phase and three phase transformers on FEM platform
CO4: Design and analyse squirrel cage induction machine on Rmxprt and Motor CAD

Lecture Sessions:

Introduction to ANSYS Maxwell Interface

Maxwell desktop interface - Maxwell 2-D and 3-D simulation - Graphics and view settings for 2-D and 3-D simulation - Types of simulation - Magnetostatic and transient simulation - Eddy current simulation - Basic drawing and geometry operation - Material assignment - Force, torque and matrix calculation - Virtual and lorentz force - Magnetostatic and transient solution of a rotational actuator - Transient simulation of 2-D rotational actuator

Mesh, Boundary, Excitation and Motion Settings

Mesh settings - Length based mesh, Element based mesh, Surface approximation, Skin depth based mesh, Trade off between mesh density and solution accuracy
Boundary settings - Vector potential, Balloon, Odd and even symmetry, Independent and dependent boundaries, Master and slave boundaries
Excitation settings - Assigning coil terminals, Voltage excitation, Current excitation, External circuit, Integrating external circuit with magnetic geometry
Motion settings - Translational motion, Rotational motion, Non cylindrical rotational motion, Limits of motion, Constant speed operation, Mechanical transient and load torque, Band setting

Design of Single Phase and Three Phase Transformers

Plotting flux paths for a bar electromagnet - Simulation of rectangular core inductor for dc and ac excitation - Plots of time varying inductance and induced emf - Comparison of 2-D and 3-D simulation of a core type single phase transformer - Open circuit and short circuit test - 3-D simulation of three phase core type transformer - Calculation of core loss and copper loss for three phase transformer

Analysis of Induction Machine Using Rmxprt

Introduction to Rmxprt interface - Squirrel cage induction machine prototype - Constant torque and constant power simulation - Rmxprt to Maxwell transport - Flux density distribution along line and surface - Plotting torque speed characteristics - Exporting FEM data to MATLAB - Determination of equivalent circuit parameters

Motor CAD Assisted Design of Induction Machine

Introduction to Motor CAD user interface - Standard templates for available electrical machines - Basic electromagnetic simulation - Line fed induction machine - Inverter fed induction machine - Basic thermal analysis - Transfer of data from Motor CAD to MATLAB - Transfer of data from Motor CAD to ANSYS

Practical Sessions:

List of Experiments

1) Calculation of torque developed in a rotational actuator using magnetostatic analysis on Maxwell 3D platform
2) Comparison of transient performance of a rotational actuator using Maxwell 2D and Maxwell 3D platforms
3) Study the effect of boundary settings on rotating electromagnetic systems using a rotational actuator on Maxwell 2D platform
4) Calculation of inductance of a magnetic circuit in presence and in absence of an air gap using Maxwell 2D platform
5) Simulation of a single-phase transformer on Maxwell 2D platform and study the effect of finite element mesh on transformer performance
6) Study the effect of boundary settings on static electromagnetic systems using a single-phase transformer on Maxwell 2D platform
7) Open circuit and short circuit tests on a single-phase transformer using Maxwell 2D and Maxwell 3D platforms and comparison of the equivalent circuit parameters thus estimated
8) Calculation of hysteresis and eddy current losses in a three-phase transformer using Maxwell 3D platform
9) Design of a three-phase squirrel cage induction machine using RMxprt and study the variation of torque speed characteristics with variation in different design criteria
10) Comparison of torque speed characteristics of a three-phase squirrel cage induction machine under constant voltage excitation and constant current excitation using Maxwell 2D platform
11) Comparison of torque speed characteristics of a three-phase squirrel cage induction machine generated using field analysis and using equivalent circuit analysis
12) Design of a line fed three phase squirrel cage induction machine using ANSYS Motor CAD
13) Design of a voltage source inverter fed three phase squirrel cage induction machine using ANSYS Motor CAD

References:

1. ANSYS Maxwell Help; www.ansys.com
2. Getting Started with Maxwell: Designing a Rotational Actuator; www.ansys.com
3. Getting Started with Maxwell: Transient Problem; www.ansys.com
4. Induction Motor for Industrial Application - Design and Analysis with ANSYS Motor-CAD
5. Induction Motor for Power Traction Application - Design and Analysis with ANSYS Motor-CAD

EE6328E ELECTRIC VEHICLE SYSTEM ENGINEERING

Pre-requisites: Strong knowledge of power electronic circuits, dynamics of electrical machines,
digital signal processors

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Design and model Electric Motor and its drive system for EV applications
CO2: Model and analyse the battery management system
CO3: Explain the concepts of embedded system for EV
CO4: Design and model the complete EV dynamics

Electric Motors and Power Converters
Introduction to motors suitable for EV applications—Modeling of Induction motor and its characteristics-Modeling of BLDC Motor-Modeling of PMSM Motor-Modeling of switched Reluctance Motor, -Modeling of Synchronous Reluctance Motor. Thermal modeling of Motors. Efficiency calculation-Simulation in software.
Converter-Design of High gain DC/DC Converter. Design of Low voltage high current Inverter drive – design of Multilevel Inverter Drive-Efficiency calculation, Harmonic Analysis. Thermal modeling of switches

Battery Technology and Control Systems
Modeling of Batteries, Active and passive balancing of batteries, SOC and SOH estimation techniques, Battery Characterization, Thermal modeling of battery, impact of different charging methods on battery, Introduction to Battery Energy Storage Systems, Wireless power transfer (WPT) technique for EV charging

Automobile Embedded System
Introduction to Embedded Systems and Classification. ATMega 328, ARM Cortex A7 series Architecture. ARM Cortex MCU Programming- Interfacing protocols (like UART, SPI, I2C, GPIB, FIREWIRE, USB, flexray and CAN) and wireless protocols. Designing Embedded Computing Platform :(Bus Protocols, Bus Organization, Memory Devices, Memory mapped I/O, I/O Devices, I/O mapped I/O, Timers and Counters, Watchdog Timers, Interrupt Controllers, Interrupt programming), Advanced Driver Assistance System (ADAS)-sensors in ADAS system, Role of Machine Learning and Deep learning in ADAS

Electric Vehicle Architecture Design
Introduction-Kinematics of Multibody Systems-Equations of Motion of Complex Multibody Systems-Kinematics and Dynamics of the Vehicle Body-Modeling and Analysis of Wheel Suspensions-Modeling of the Road-Tire-Contact-Modeling of the Drive-train, Force Components, Single Track Models, Twin Track Models, Three-Dimensional Complete Vehicle Models, Model of a Typical Complex Complete Vehicle

References:

1. Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, *Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design*, CRC Press, 2004.
2. Iqbal Hussein, *Electric and Hybrid Vehicles: Design Fundamentals*, CRC Press, 2003.
3. Dieter Schramm , Manfred Hiller , Roberto Bardini, *Vehicle Dynamics-Modeling and Simulation*, Springer, 2014.
4. Daniel Kusswurm, *Modern Arm Assembly Language Programming: Covers Armv 8-A 32-bit, 64-bit, and SIMD*, Apress, 2020.
5. Yifeng Zhu, *Embedded Systems with ARM Cortex-M Microcontrollers in Assembly Language and C: Third Edition*, E-Man Press LLC, 2017.
6. James Larminie, John Lowry, *Electric Vehicle Technology Explained*, Second Edition, Wiley, 2012.
7. Kenjo T and Nagamoris, *Permant Magnet & Brushless DC motor*, Clarendon Press, Oxford, 1989.
8. W.Shephered, L N Hulley Cambride, *Power Electronics & Control of Motor*, University Press, 2005.
9. Ned Mohan, *Power Electronics Converter, Applications, and Design*, Third Edition, Wiley, 2002.
10. Gerardus Blokdyk, *Advanced Driver Assistance Systems ADAS: A Complete Guide*, 2018.
11. Yan Li and Hualiang Shi, *Advanced Driver Assistance Systems and Autonomous Vehicles From Fundamentals to Applications*, Springer, 2022.
12. I. Boldea, *Reluctance Synchronous Machines and Drives*, Clarendon Press, 1996.

EE6329E ADVANCED MICROPROCESSOR BASED SYSTEMS

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand the number system necessary for programming a microprocessor
CO2: Understand the memory space and CPU architecture of a microprocessor
CO3: Perform assembly coding and design programs for performing specific applications
CO4: Configure the microprocessors for generating PWM pulses

Introduction
Fixed point number system - Difference between microprocessors and microcontrollers - Programming a processor - Advantages of assembly language programming over C language programming

PIC18 Architecture and Assembly Language Programming

RISC architecture in the PIC - MPLAB simulator - Assembling and Linking a PIC program - Program counter - Memory organization - Program memory and data memory - WREG register - Status register - Special function registers - PIC18 pin connection - Configuration registers

Programming the PIC18 Microcontroller

Types and categories of PIC18 instructions - Addressing modes - Working with look up tables - Macros - PIC18 interrupts - Branch instructions and loop - Call instructions and stack - Instruction pipeline - Arithmetic instructions - Programming for signed and unsigned numbers - Programming for 2’s compliment - Logic and compare instructions - I/O port programming - I/O bit manipulation programming

Hardware Interfacing

Timer modules - Programming the timer control registers - Counter programming - LCD and keyboard interfacing - Programming the ADC - DAC and sensor interfacing - CCP and ECCP modules - PWM and ECCP programming - Relays and opto-isolators - Stepper motor interfacing - DC motor control with ECCP

References:

1. Muhammad Ali Mazidi, Rolind D. Mckinlay and Danny Causey, *PIC Microcontroller and Embedded Systems (Using Assembly and C for PIC18)*, Pearson, 2021.
2. Martin Bates, *PIC Microcontrollers: An Introduction to Microelectronics*, Newnes Publishers, 2011.
3. PIC18FXX2 Data Sheet, www.microchip.com

ZZ6001E RESEARCH METHODOLOGY

Pre-requisites**: NIL**

L	T	P	O	C
2	0	0	4	2

Total Lecture sessions: 26

Course Outcomes

CO1**:** Explain the basic concepts and types of research
CO2**:** Develop research design and techniques of data analysis
CO3: Develop critical thinking skills and enhanced writing skills
CO4**:** Apply qualitative and quantitative methods for data analysis and presentation
CO5**:** Implement healthy research practice, research ethics, and responsible scientific conduct

Exploring Research Inquisitiveness

Philosophy of Scientific Research, Role of Research Guide, Planning the Research Project, Research Process, Research Problem Identification and Formulation, Variables, Framework development, Research Design, Types of Research, Sampling, Measurement, Validity and Reliability, Survey, Designing Experiments, Research Proposal, Research Communication, Research Publication, Structuring a research paper, structuring thesis/ dissertation,

Research Plan and Path

Developing a Research Plan: Reviewing the literature- Referencing – Information sources – Information retrieval – Role of libraries in information retrieval – Tools for identifying literatures – Reading and understanding a research article – Critical thinking and logical reasoning; Framing the research hypotheses, Converting research Question into a Model; Data collection- Types of data-Dataset creation- Primary and Secondary data- Scales of measurement- Sources and collection of data- Processing and analysis of data-Understanding Data-statistical analysis, displaying of data-Data visualization-Data interpretation; Research design- Qualitative and Quantitative Research- Designing of experiments- Validation of experiments- Inferential statistics and result interpretation

Scientific Conduct and Ethical Practice

Plagiarism– Ethics of Research- Scientific Misconduct- Forms of Scientific Misconduct. Plagiarism, Unscientific practices in thesis work-Conduct in the workplace and interaction with peers – Intellectual property: IPR and patent registration, copyrights; Current trends – Usage and ethics of AI tools in scientific research.

References:

1. Leedy, P D, *Practical Research: Planning and Design,* USA: Pearson, Twelfth ed., 2018.
2. Krishnaswamy, K. N., Sivakumar, A. I., and Mathirajan, M., *Management Research Methodology*, Pearson Education, 2006.
3. Tony Greenfield and Sue Greener., *Research Methods for Postgraduates,* USA: John Wiley & Sons Ltd., Third ed., 2016.
4. John W. Creswell and J. David Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, USA: Sage Publications, Sixth ed., 2022.

MS6174E TECHNICAL COMMUNICATION AND WRITING

Pre-requisites: **NIL**

L	T	P	O	C
2	1	0	3	2

Total Lecture Sessions: 26

Course Outcomes:

CO1: Apply effective communication strategies for different professional and industry needs.

CO2: Collaborate on various writing projects for academic and technical purposes.

CO3: Combine attributes of critical thinking for improving technical documentation.

CO4: Adapt technical writing styles to different platforms.

Technical Communication
Process(es) and Types of Speaking and Writing for Professional Purposes - Technical Writing: Introduction, Definition, Scope and Characteristics - Audience Analysis - Conciseness and Coherences - Critical Thinking - Accuracy and Reliability - Ethical Consideration in Writing - Presentation Skills - Professional Grooming - Poster Presentations

Grammar, Punctuation and Stylistics
Constituent Structure of Sentences - Functional Roles of Elements in a Sentence - Thematic Structures and Interpretations - Clarity - Verb Tense and Mood - Active and Passive Structures - Reporting Verbs and Reported Tense - Formatting of Technical Documents - Incorporating Visuals Elements - Proofreading

Technical Documentation
Types of Technical Documents: Reports, Proposals, Cover Letters - Manuals and Instructions - Online Documentation - Product Documentation - Collaborative Writing: Tools and Software - Version Control Document Management - Self Editing, Peer Review and Feedback Processes

References:

1. Foley, M., & Hall, D., *Longman advanced learner's grammar, a self*-study *reference & practice book with answers*. Pearson Education Limited, 2018.
2. Gerson, S. J., & Gerson, S. M., *Technical writing: Process and product*, Pearson, 2009.
3. Kirkwood, H. M. A., & M., M. C. M. I., Hallidays, *Introduction to functional grammar* (4th ed.), Hodder Education, 2013.
4. Markel, M., *Technical Communication* (10th ed.). Palgrave Macmillan, 2012.
5. Tuhovsky, I., *Communication skills training: A practical guide to improving your social intelligence, presentation, Persuasion and public speaking skills*, Rupa Publications India, 2019.
6. Williams, R., *The Non-designer's Design Boo*k. Peachpit Press, 2014.

IE6001E ENTREPRENEURSHIP DEVELOPMENT

Pre-requisites: **NIL**

L	T	P	O	C
2	0	0	4	2

Total Lecture Sessions: 26

Course Outcomes:

CO1: Describe the various strategies and techniques used in business planning and scaling ventures.
CO2: Apply critical thinking and analytical skills to assess the feasibility and viability of business ideas.
CO3: Evaluate and select appropriate business models, financial strategies, marketing approaches, and operational plans for startup ventures.
CO4: Assess the performance and effectiveness of entrepreneurial strategies and actions through the use of relevant metrics and indicators.

Entrepreneurial Mindset and Opportunity Identification

Introduction to Entrepreneurship Development - Evolution of entrepreneurship, Entrepreneurial mindset, Economic development, Opportunity Recognition and Evaluation - Market gaps - Market potential, Feasibility analysis - Innovation and Creativity in Entrepreneurship - Innovation and entrepreneurship, Creativity techniques, Intellectual property management.

Business Planning and Execution

Business Model Development and Validation - Effective business models, Value proposition testing, Lean startup methodologies - Financial Management and Funding Strategies - Marketing and Sales Strategies - Market analysis, Marketing strategies, Sales techniques - Operations and Resource Management - Operational planning and management, Supply chain and logistics, Stream wise Case studies.

Growth and Scaling Strategies

Growth Strategies and Expansion - Sustainable growth strategies, Market expansion, Franchising and partnerships - Managing Entrepreneurial Risks and Challenges - Risk identification and mitigation, Crisis management, Ethical considerations - Leadership and Team Development - Stream wise Case studies.

References:

1. Kaplan, J. M., Warren, A. C., & Murthy V., *Patterns of entrepreneurship management.* John Wiley & Sons, 2022.
2. Kuratko, D. F., *Entrepreneurship: Theory, Process, and Practic*e. Cengage learning.
3. Barringer, B. R., *Entrepreneurship: Successfully launching new ventures*, Pearson Education India, 2015.
4. Rajiv Shah, Zhijie Gao, Harini Mittal, I*nnovation, Entrepreneurship, and the Economy in the US, China, and India,* Academic Press, 2014.
5. Sundar,K., *Entrepreneurship Developmen*t, 2nd Ed., Vijaya Nichkol Imprints, Chennai, 2022. E. Gordon,Dr. K. Natarajan., *Entrepreneurship Development*, 6th Ed, Himalya Publishers, Delhi, 2017.
6. Debasish Biswas, Chanchal Dey, *Entrepreneurship Development in India*, Taylor & Francis, 2021.