<u>Department of Electrical Engineering</u>

"Draft Curriculum and Syllabi for M. Tech. in Power Electronics and Drives (PED)"

With effect from 2025 entry batch

Mission and Vision Statement
of
Electrical Engineering Department

The mission of the Electrical Engineering Department is to impart quality education to our students and provide a comprehensive understanding of electrical engineering, built on a foundation of physical science, mathematics, computing and technology and to educate a new generation of Electrical Engineers to meet the future challenges.

The Vision of Electrical Engineering Department is to be a model of excellence in technical education and research by producing world-class graduates who are prepared for life-long engagement in the rapidly changing fields of electrical and related fields.

Program Educational Objectives (PEOs)

PEO1: The postgraduates of PED will demonstrate their skills that will enable them to evaluate and analyze new developments in Power Electronics and Drives.

PEO2: The postgraduates of PED will demonstrate their skill to undertake significant research and or developmental projects, even in multidisciplinary environments to meet the societal requirements.

PEO3: The PED postgraduates will demonstrate their professional, ethical and social attitude /behavior, and show respect for diversity and global issues during professional career.

PO Statements (POs):

PO1: An ability to independently carry out research /investigation and development work to solve practical problems.

PO2: An ability to write and present a substantial technical report/document.

PO3: Students should be able to demonstrate a degree of mastery over the area of Power Electronics and Drives. The mastery should be at a level higher than the requirements in the bachelor program of Electrical Engineering.

PO4: Students should be able to work independently/ in a team maintaining high ethical values to provide real-time solutions for social, environmental and economic issues.

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Course Structure

Semester I

S. N.	Code	Subject	L	T	P	Credits
1	EE 5301	Advanced Power Electronics	3	0	0	3
2	EE 5302	Electric Drives and Systems	3	0	0	3
3	EE 5303	Switched Mode Power Supply	3	0	0	3
4	EE 5304	Power Converters Laboratory	0	0	3	2
5	EE 5310	Seminar-I	0	0	2	1
6	EE 53XX	Elective – I	3	0	0	3
7	EE 53XX	Elective – II	3	0	0	3
		Total contact hours/credits	15	0	5	18

Semester II

S. N.	Code	Subject	L	T	P	Credits
1.	EE 5311	Modelling and Control of Electrical Machines	3	0	0	3
2.	EE 5312	Grid-Connected Power Converters	3	0	0	3
3	EE 5313	Pulse Width Modulations for Power Converters	3	0	0	3
4.	EE 5314	Energy Conversions and Drives Laboratory	0	0	3	2
5.	EE 5315	Seminar-II	0	0	2	1
6.	EE 53XX	Elective – III	3	0	0	3
7.	EE 53XX	Elective – IV	3	0	0	3
8.	EAA	Extra Academic Activities (Yoga)	0	0	2	0
		Total contact hours/credits	15	0	7	18

Semester: III and IV

S. N.	Code	Subject	L	T	P	Credits	Semester
1	EE 6398	Project Phase -I	-	-	-	06	III
2	EE 6399	Project Phase -II	-	-	-	08	IV
		Total contact hours/Credits	-	-	-	14	---

Electives I

S. N.	Code	Subject	*Prerequisites, if any*
1.	EE 5320	Advanced Power Semiconductor Devices and Passive Components	
2.	EE 5321	Power Electronics in Power Transmission System	
3.	EE 5322	Power Electronics for Photovoltaic and Wind Energy Systems	
4.	EE 5323	Advanced Materials for Power Electronic Devices	

Electives II

S. N.	Code	Subject	*Prerequisites, if any*
1.	EE 5340	Power Quality and Conditioning in Power Distribution System	
2.	EE 5341	Intelligent Control Techniques	
3.	EE 5342	Energy Storage Systems	
4.	EE 5343	Smart Grid and Distribution Automation	
5.	EE 5344	Multipulse and Multilevel Converters	

Electives III

S. N.	Code	Subject	*Prerequisites, if any*
1.	EE 5360	Electric and Hybrid Vehicles	
2.	EE 5361	AC/DC Microgrids	
3.	EE 5362	Low Voltage Power Electronics	
4.	EE 5363	Special Electromechanical Systems	
5.	EE 5364	Modern Control Theory	

Electives IV

S. N.	Code	Subject	*Prerequisites, if any*
1.	EE 5380	Advanced Topics on Power Electronics Converters	
2.	EE 5381	Electric Traction and Control	
3.	EE 5382	Digital Controller for Power Electronics Converters	
4.	EE 5383	Energy Efficiency, Auditing and Loss Reduction	
5.	EE 5384	Thermal Design for Heat Sinks, Thermoelectric and EMI/EMC Requirements	

	Advanced Power Electronics	**L**	**T**	**P**	**C**
EE 5301	**M. Tech in Power Electronics and Drives**	**3**	**0**	**0**	**3**
	Electrical Engineering Branch				

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid semester examination, surprise tests, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Introduction to semiconductor switches

Introduction, basics of Silicon devices - Silicon HV thyristors, diodes, BJTs, MOSFETs & IGBTs, gate driver circuitry for semiconductor switching devices, snubber circuit and thermal design, basic of Silicon carbide and Gallium Nitrate based devices.

Unit 2: AC-DC Converters

Single phase diode rectifier, Three phase rectifier, Power factor improvement methods, Pulse-Width Modulation (PWM) controlled rectifier circuits and its control.

Unit 3: DC-AC Converters

Principle of operation, single phase half and full bridge inverters Voltage control of single-phase inverters: single/multiple pulse/SPWM/ modified SPWM methods, Voltage control of three phase inverter: SPWM/third harmonic included PWM, Harmonic reduction, Current source inverter

Unit 4: DC-DC Converters

Limitations of linear power supplies, Switched Mode Power Conversion, Non-isolated DC-DC Converters: Principle of operation, analysis of step-down and step-up converters, interleaved converter, switched capacitor converter.

Unit 5: Soft switching Converters

Introduction to resonant converters, classification of resonant converters, series load resonant converter, zero voltage and current switching resonant converter.

Text Books:

1. Ned Mohan, Tore. M. Undeland and William. P Robbins, “Power Electronics: Converters, Applications and Design”, John Wiley and Sons.
2. Daniel W. Hart. Power Electronics. TMH
3. Marian P. Kazmierkowski, R Krishnan and Frede Blaabjerg, “Control in Power Electronics”, Academic Press.

Reference Books:

1. Thomas H. Barton, “Rectifiers, Cycloconverters and AC controllers”, Clarendon Press, Oxford.

2. William Shepherd and Li Zhang Power, "Power Converter Circuits", Marcel Dekker Inc.
3. Fang Lin Luo, Hong Ye and Muhammad Rashid, "Digital Power Electronics and Applications", Academic Press.
4. Robert W. Erickson, "Fundamentals of Power Electronics", Kluwer Academic Publishers.
5. Barry W Williams, "POWER ELECTRONICS: Devices, Drivers, Applications, and Passive Components", McGraw Hill.
6. Marian K. Kazimierczuk, "Pulse-width Modulated DC–DC Power Converters", John Wiley & Sons.
7. Muhammad H. Rashid and Hasan M. Rashid, "SPICE for Power Electronics and Electric Power", CRC Press.

Course Outcomes: At the end of this course, students will be able to:

1. Identify and select power electronic semiconductor switches
2. Analyze the operation of converters in various application.
3. Design and develop control strategies for efficient operation of converters.

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO1	2	2	2	1
CO2	2	2	2	2
CO3	2	2	2	2

3- High, 2- Medium, 1-Low

	Electric Drives and Systems	**L T P C**
EE 5302	**M. Tech in Power Electronics and Drives**	**3 0 0 3**
	Electrical Engineering Branch	

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid semester examination, surprise tests, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Fundamentals of Electric Drives

Concept of Electrical Drive, Dynamics of Electrical Drives: Fundamental torque equation, Nature and classification of load torques, drive classifications, closed-loop control of drives: current-limit control, torque control, speed control, speed control of multi-motor drives, Speed sensing, current sensing, phase-locked-loop (PLL) control, closed-loop position control, transient analysis of ac and dc drives

Unit 2: Control of DC motor Drives

Review of Starting and Braking of DC Motor, Converter Control of DC Drives: Analysis of DC motor with single phase and three phase converters operating in different modes and configurations, Dual converter fed DC Drive; Chopper Control of DC Drives: steady state operation, Single quadrant and four quadrant variable speed chopper fed DC Drives with closed loop operation.

Unit 3: Control of Induction motor drives

Review of Starting and Braking of Induction Motor, Induction motor drive: Three phase induction motor operation from sinusoidal and non-sinusoidal supply, speed control methods: voltage control at constant frequency, speed control of wound rotor induction motors: static rotor resistance control and static slip power control, variable frequency operation from voltage sources and current sources. current controlled PWM VSI with hysteresis band

Unit 4: Control of Synchronous motor drives

Synchronous motor drive: Review of cylindrical rotor and salient pole synchronous machine: operating principles, characteristic equations, phasor diagram, true and self-synchronous control, load commutated inverter fed synchronous motor, constant V/f control, scalar control with unity power factor, Cyclo-converter fed synchronous motor Drives

Unit 5: Advanced Motor Drives

Brushless DC motor drive, Permanent magnet synchronous motor drives: surface permanent magnet machine and interior permanent magnet motors, Stepper motor drives, Switched reluctance motor drives

Text Books:

1. G. K. Dubey, Power Semiconductor Controlled Drives, Prentice-Hall International, New Jersey, 1989
2. G.K. Dubey. Fundamentals of Electrical Drives. Narosa
3. S.K. Pillai. A first course on Electrical Drives. Willey Eastern Ltd.
4. V. Subrahmanyam. Electric Drives. New Age

Reference Books:

1. W. Leonhard, Control of Electrical drives, Springer-Verlag, Berlin, 1985
2. B. K. Bose, Modern Power Electronics and AC Drives, Pearson Education Inc., Singapore, 2002

Course Outcomes: At the end of this subject, students will be able to:

1. Analyze the basic concepts of DC and AC drives.
2. Evaluate the control techniques of converter fed DC drives
3. Analyze the scalar control techniques for induction motor drives
4. Examine the control techniques for Synchronies motor drives
5. Describe control methodology of different advanced motor drives

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	3	3	2	2
CO 2	3	3	2	1
CO 3	3	3	2	2
CO 4	3	3	2	1
CO 5	3	3	2	1

3- High, 2- Medium, 1-Low

EE 5303	**Switched Mode Power Supply** **M. Tech in Power Electronics and Drives** **Electrical Engineering Branch**	**L T P C** **3 0 0 3**

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid semester examination, surprise tests, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Introduction and basic switched mode power converter topologies

Introduction to switch mode power supplies (SMPS), non-isolated dc-dc switch mode converters and analysis: buck, boost, CUK, SEPIC, non-idealities in the SMPS; isolated dc-dc switch mode converters and analysis: fly-back, forward, push-pull, half-bridge and full-bridge topologies; dc-ac switched mode driven inverters.

Unit 2: Modeling and control of SMPS

Dynamic modeling using generalized state-space average method to obtain small-signal linear model of the switch mode power converters under CCM and DCM, input and control transfer functions of converters, closed loop control, voltage mode and current model control, instability in current control and slope compensation technique, methods of regulating multi-output power supply, unity power factor converter.

Unit 3: Resonant SMPS

Review of resonant converter topologies and principle of operations: Resonant load converters, resonant inverter based SMPS, full power circuit of a resonant load SMPS; resonant transition phase modulated converters, resonant switching converters with active clamp.

Unit 4: Design considerations and protections of SMPS

Selection of filter capacitors and selection of energy storage inductor, transformer design for high frequency isolation, design of DC-DC converter, EMI Filter components, conducted EMI suppression, radiated EMI suppression, measurement and protection.

Unit 5: Applications of SMPS

Active front end – power factor correction, High frequency power source for fluorescent lamps, power supplies for portable electronic gadgets.

Text Books:

1. V. Ramanarayanan. Course Material on Switched Mode Power Conversion. Department of Electrical Engineering, Indian Institute of Science, Bangalore
2. Philip T. Krein. Elements of Power Electronics. Oxford University Press

Reference Books:

1. Ned Mohan, Tore M. Undeland and William P. Robbins. Power Electronics: Converters, Applications and Design. John Wiley & Sons, Inc.
2. L. Umanand. Power Electronics: Essentials and Applications. Wiley India
3. Ned Mohan, Tore M. Undeland and William P. Robbins. Power Electronics: Converters, Applications and Design. John Wiley & Sons, Inc.
4. Keith H Billings and Taylor Morey. Switch mode power supply handbook. Mc-Graw hill Publishing Company
5. Sanjaya Maniktala. Switching power supplies A to Z. Elsevier
6. Switch mode power supply: Reference Manual on Semiconductor. SMPSRM/D. Rev, 4, Apr-2014, SCILLC.
7. Seddik Bacha, Lulian Munteanu and Antoneta Luliana Bratcu. Power Electronic Converters Modeling and Control: with Case Studies. Springer.

Course Outcomes: At the end of the course the students will be able to:

1. Analyze the operations of various dc-dc and dc-ac switch mode power converter topologies.
2. Develop the dynamic model for the control of different switch mode dc-dc power converters.
3. Evaluate the performances of different switch mode dc-dc power converters
4. Design considerations and protections of SMPS and its various industrial applications.

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO1	2	2	2	1
CO2	3	3	3	2
CO3	2	2	2	1
CO4	3	3	3	3

3- High, 2- Medium, 1-Low

	Power Converters Laboratory	**L T P C**	
EE 5304	**M. Tech in Power Electronics and Drives**	**0 0 3 2**	
	Electrical Engineering Branch		

List of Experiments:

1. Performance Analysis of Buck, Boost and Buck-Boost and Interleaved Boost/Boost converters
2. Three phase inverters operating under 120° and 180° modes
3. Three phase AC-AC voltage regulator with R, RL loads
4. Study power factor correction using buck-boost converter
5. DC-to-DC Switched Mode Converters.
6. 1- Φ & 3- Φ Inverter with square wave, quasi-square wave and SPWM Control
7. Speed control of permanent magnet DC motor drive fed from single phase thyristor bridge fully controlled converter using armature voltage control method
    - Analog mode
    - Digital PID Mode
8. Closed loop speed control of separately excited DC motor drive fed from single and three phase thyristor bridge fully controlled converters using armature voltage and field control.
9. Speed control of three phase slip-ring induction motor drive using slip power recovery scheme
10. Speed control of three phase induction motor (V/F Control)

Course Outcomes: At the end of the course the students will be able to

1. Design and analyse the performance of DC-DC Converters.
2. Design and analyse the performance of Inverters.
3. Design and develop closed loop control systems for different DC and Induction machine drives.

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	3	3	3	3
CO 2	3	3	3	3
CO 3	3	3	3	3

3- High, 2- Medium, 1-Low

EE 5310	SEMINAR I M. Tech in Power Electronics and Drives First Semester	L	T	P	C
		0	0	2	1

Course Outcome of Seminar:

At the end of seminar course, students are expected to be able to:

1. Prepare good slides and present a particular topic effectively.
2. Develop team spirit and leadership qualities through group activities.
3. Develop confidence for self-learning and overcome the fear of public presentations.
4. Update knowledge on contemporary issues, prepare technical report and do presentations on these issues.
5. Learn technical editing software Latex and write technical report using Latex.

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	3	3	3	3
CO 2	3	3	3	3
CO 3	3	3	3	3
CO 4	3	3	3	3
CO 5	3	3	3	3

3- High, 2- Medium, 1-Low

EE 5320	**Advanced Power Semiconductor Devices & Passive Components** **M. Tech in Power Electronics and Drives** **Electrical Engineering Branch**	**L T P C** **3 0 2 0**

Pre-requisites: Power Electronics

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Power Diodes and BJTs

Basic Structure, I-V and switching characteristics of diodes and BJTs, On-state Losses, Reverse Recovery Transients, Snubber Design, Heat transfer by conduction, transient thermal impedance, heat transfer by radiation and convection, Heat Sink Selection. Latest topics of packaging technology for power devices.

Unit 2: Power MOSFETs and IGBTs

Basic Structure of MOSFET, V-I and switching characteristics, Transient Analysis, Switching Losses, Gate Driver circuits for Power semiconductor devices, Snubber design; Basic Structure and Operation of IGBTs, IGBT Switching Characteristics, Transient analysis, Switching Losses, Snubber Design.

Unit 3: New power semiconductor devices

Wide bandgap semiconductors and devices- SiC Diodes, SiC-MOSFETs, GaN devices, V-I Characteristics, Switching model, Driver requirements, Applications.

Unit 4: Passive component selection

Type of capacitors, dielectric losses, high frequency operation, unipolar and bipolar capacitors, ESL and ESR of capacitors, application, Transmission - Cables, wires, high frequency limitations, optical fiber, interfacing; Transducers for non-electrical quantities such as pressure, temperature, flow etc., Filters, passive filters, active filters, filter components, EMI, effects, suppression, EMI compatibility noise, Fuses, circuit breakers, coordination, surges and surge suppressors.

Unit 5: Magnetics

Fundamentals of Magnetics, Advanced magnetics material, technology and design (Powder ferrite, Amorphous, Planar designs), losses in magnetic components, applications Magnetization Processes, Inductor and transformer design.

Text Books:

1. Ned Mohan Tore.M. Undeland and William.P Robbins, “Power Electronics converters, Applications and Design”, John Wiley and Sons.

2. B. JayantBalinga, 'Advanced High Voltage Power Device Concepts', Springer New York 2011. ISBN 978 -1- 46140268-8
3. L Umanand and S R Bhat, “Design of Magnetic Components for Switched Mode Power Converters”, New Age International

Reference Books:

1. G. Massobrio, P. Antognetti, “Semiconductor Device Modeling with Spice”, McGraw-Hill.
2. V. Benda, J. Gowar, and D. A. Grant, “Discrete and Integrated Power Semiconductor Devices: Theory and Applications”, John Wiley & Sons.
3. Barry W Williams,"POWER ELECTRONICS: Devices, Drivers, Applications, and Passive Components", McGraw Hill.
4. Alex Van den Bossche and Vencislav Cekov Valchev,"Inductors and Transformers for Power Electronics", CRC Press, Taylor & Francis Group.
5. Gourab Majumdar, Ikunori Takata, "Power Devices for Efficient Energy Conversion," ISBN 9789814774185, Pan Stanford Publishing, 2018
6. Wurth Electronics, 'Trilogy of Magnetics, Design guide for EMI filter design in SMPS & RF circuits', 4th extended and revised edition.

Course Outcomes: At the end of this course, students will be able to:

1. Analyze the operation of Power Diodes, BJTs
2. Analyze the operation of Power MOSFETs, IGBTs and gate driving circuits
3. Recognize modern semiconductor devices
4. Design thermal and magnetic requirements for power electronics converters

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO1	2	2	2	2
CO2	3	3	3	2
CO3	2	2	2	1
CO4	3	3	3	3

3- High, 2- Medium, 1-Low

	Power Electronics in Power Transmission System	**L**	**T**	**P**	**C**
EE 5321	**M. Tech in Power Electronics and Drives**	**3**	**0**	**0**	**3**
	Electrical Engineering Branch				

Pre-requisites: Power Electronics, Power System, Electrical Machines

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: HVDC Transmission

General aspects of DC transmission, Power Handling Capabilities of HVDC lines, Basic Conversion principles, static converter configurations and their analysis, Converter station and terminal equipment communication process, Rectifier and inverter operation, equivalent circuit for Converter- special futures of converter transformers, Principle of DC link control, Converter control characteristics (both for rectifier and inverter end), Power flow controller characteristics (forward and reverse power flow), HVDC system control hierarchy, faults and abnormal operation and protection

Unit 2: Flexible AC transmission systems (FACTS) Controllers

Steady state and dynamic problems in AC systems. Flexible AC transmission systems (FACTS). Principles of series and shunt compensation. comparison between series and shunt capacitor compensation, Modelling and Analysis of FACTS controllers. Control strategies to improve system stability.

Unit 3: Shunt Compensation

Objectives of shunt compensation, Variable impedance types static VAR generators: Analysis of static var compensators (SVC), TSC and TCR, voltage source converter type VAR generators: Static Synchronous Compensator (STATCOM)

Unit 4: Series Compensation

Objectives of series compensation, variable impedance type series compensators: Thyristor-Controlled Series Capacitor (TCSC), GTO Thyristor-Controlled Series Capacitor (GCSC), voltage source converter type series compensators: Static Synchronous Series Compensator (SSSC)

Unit 5: Combined Shunt and Series Compensators

Basic operating principles and characteristics: Unified Power Flow Controllers (UPFC), Interline Power Flow Controller (IPFC)

Unit 6: Generation of High Voltage and Currents

DC – Voltage doubler – Cascade circuit, AC voltage – cascade transformer – series resonance circuits.

Text Books:

1. K. R. Padiyar. HVDC Power Transmission Systems, Technology and System Interactions. New Age International
2. K. R. Padiyar. FACTS controllers in power transmission and distribution. New Age International
3. Narain G. Hingorani and Laszlo GyuGui, Understanding FACTS Concepts and Technology of Flexible AC Transmission Systems, IEEE Press

Reference Books:

1. Vijay K. Sood, HVDC and FACTS Controllers Applications of Static Converters in Power
2. T. J. E. Miller. Reactive power control in Electrical system. John Wiley & Sons
3. R.D. Gegamudre. Extra High Voltage AC Transmission Engineering, New Age International Publisher.

Course Outcomes: Upon completion of the course the students would be able to:

1. Describe the principle of HVDC conversion technologies
2. Analyse the modes of operations of HVDC converters for the DC-link control
3. Classify FACTS controller configuration
4. Analyse shunt and series type FACTS controllers with their control philosophy
5. Select the appropriate EHAV / HVDC transmission systems

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	3	3	2	1
CO 2	3	3	2	2
CO 3	3	3	2	1
CO 4	3	3	2	2
CO 5	3	3	2	3

3- High, 2- Medium, 1-Low

	Power Electronics for Photovoltaic and Wind Energy Systems	**L**	**T**	**P**	**C**
EE 5322	**M. Tech in Power Electronics and Drives**	**3**	**0**	**0**	**3**
	Electrical Engineering Branch				

Pre-requisites: Electrical Machines, Power Electronics

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Introduction to Energy Sources

Recent trends in energy consumption, world energy scenario, energy sources and their availability, conventional and renewable sources, need to develop new energy technologies, qualitative study of different types of dispatchable and non-dispatchable energy resources, different types of energy storage suitable of wind and solar.

Unit 2: Solar Photovoltaic (SPV) System

Introduction to solar energy, solar radiation and measurement, PV solar cell, one diode and two diode modeling of PV cell, series and parallel connection of PV cell, P-V&I-V characteristics, effect of change in insolation and temperature on PV cell, partial shading, blocking and bypass diode, Units, MPPT algorithms

Unit 3: Converter Interface for Solar PV System and Battery Storage

Review of buck, boost and fly back dc-dc converters, 1-phase and 3-phase inverters, control schemes: unipolar, bipolar, need for storage, different types of battery suitable for SPV, characteristics and parameters, charging schemes of battery, off-grid and grid connected SPV system, PLL and synchronization, single and double stage control for SPV system, power processing, grid connection issues.

Unit 4: Introduction to Wind Energy Conversion Systems (WECS)

Basic principle of wind energy conversion, Betz limit, aerodynamics principle, drag and lift force, phasor representation, power-speed characteristics, components of a wind energy conversion system (WECS), mechanical control, MPPT algorithm, Types of WECS, choice of generators.

Fixed speed WECS: squirrel cage induction generator: working principle, generator model for steady state and transient stability analysis, grid connected and standalone operation of SCIGs

Unit 5: Variable speed WECS

Need of variable speed systems, power-wind speed characteristics, Doubly Fed Induction Generator (DFIG) and Permanent Magnet Synchronous Generator (PMSG) based WECS - their different operating modes, steady-state equivalent circuit, performance characteristics, operation of DFIGs and PMSGs with different power electronic converter configurations for standalone and grid connected operation, power control strategies, reactive power and voltage control, case studies on power control strategies.

Unit 6: Power quality issues and Wind interconnection requirements

Indian wind grid code, Low-Voltage Ride Through (LVRT), power quality issues associated with grid connected generators, current practices and industry trends, generator sizes, technology and location (off shore versus on shore), control strategies for power control under distorted grid conditions (case studies).

Text Books:

1. Chetan Singh Solanki. Solar Photovoltaics: fundamentals, Technologies, and Applications. Prentice Hall of India.
2. S. N. Bhadra, D. Kastha& S. Banerjee. Wind Electrical Systems. Oxford university press.
3. Siegfried Heier, Rachel Waddington. Grid Integration of Wind Energy Conversion Systems. Wiley.

Reference Books:

1. Remus Teodorescu, Marco Liserre, Pedro Rodriguez. Grid Converters for Photovoltaic and Wind Power Systems. Wiley Publications.
2. Mukund R. Patel. Wind and Solar Power Systems: Design, Analysis, and Operation. CRC Taylor & Francis.
3. Marcelo Godoy Simoes and Felix A. Farret. Renewable Energy Systems: Design and Analysis with Induction Generators. CRC Press.
4. Ion Boldea. Variable speed generators. CRC press.

Course Outcomes: At the end of the course the students will be able to

1. Analyze the various Non-Conventional sources of energy and storage.
2. Examine the characteristics of solar PV systems.
3. Analyze converters for Solar PV system in off grid and grid connected modes.
4. Understand the performance of fixed speed and variable speed and different converters for wind energy conversion systems.

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	3	3	2	1
CO 2	3	3	2	1
CO 3	3	3	2	1
CO 4	3	3	2	1

3- High, 2- Medium, 1-Low

EE 5323	Advanced Materials for Power Electronic Devices M. Tech in Power Electronics and Drives Electrical Engineering Branch	L	T	P	C
		3	0	0	3

Pre-requisites: Power Electronics, Power Systems, High Voltage Engineering.

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid semester examination, surprise tests, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Introduction to Materials

Review of different materials in power electronics, various relevant high voltage tests, tools available, basics of material fabrication and design, insulation properties and related measurements, thermal properties, microscopic characterization, dielectric spectroscopy, relevant test standards.

Unit 2: Solid State Transformer (SST)

Basics of SST and medium frequency transformer, review of applications in different areas, design of SST and MFT, various insulation and core materials used in SSTs and MFTs, design of SST and MFT materials for the electric vehicle application, effect of high frequencies and temperatures on the design of SSTs and MFTs, prototype studies.

Unit 3: Role of Harmonics in Material Design

Basics of harmonics, impact of harmonics in the design of cables used in HVDC, SSTs, and electric vehicles, life assessment, preparation of degradation-resistant materials, surface functionalization of nanofillers.

Unit 4: Materials in Power Electronic Units and Packaging

Basics of power electronic Units, limitations of presently used materials, performance under composite AC/DC signals, fabrication of new materials: epoxy resin micro, nano, and hybrid composites; role of interphase, analysis of high temperature performance, state-of-the-art technologies.

Text Books:

1. Electrical Degradation and Breakdown in Polymers, Dissado L. A., and John C. Fothergill, Vol. 9. IET, 1992.
2. Advanced Nanodielectrics: Fundamentals and Applications, Tanaka, Toshikatsu and Takahiro Imai, CRC press, 2017.

Reference Books:

1. Advanced Materials for Thermal Management of Electronic Packaging, Tong, X. C., vol. 30, Springer Science & Business Media, 2011.
2. Principles of Electronic Materials and Devices, Kasap, S.O., (Vol. 2). McGraw-Hill,

2006.

3. High voltage engineering fundamentals, Kuffel, John, and Peter Kuffel, Elsevier, 2000.

Course Outcomes: At the end of this course, students will be able to:

1. Apprehend the fundamental concepts of materials used for power electronic devices.
2. Identify the characterization and measurement tools for material testing.
3. Design the insulation for solid state transformer.
4. Analyze the role of harmonics in the material design of power electronic devices.
5. Design different materials for power electronic packaging

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	3	3	2	1
CO 2	3	3	2	1
CO 3	3	3	2	3
CO 4	3	3	2	1
CO 5	3	3	2	3

3- High, 2- Medium, 1-Low

Power Quality and Conditioning in Power Distribution System

		L	T	P	C
EE 5340	**M. Tech in Power Electronics and Drives** **Electrical Engineering Branch**	**3**	**0**	**0**	**3**

Pre-requisites: Power Electronics

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Power Quality

Overview and definition of Power Quality (PQ), classification and characteristics of different PQ problems, Sources of Pollution, International PQ standards and regulations, Power Acceptability curves- their necessity and utilization.

Unit 2: Voltage Sag, Swell, Transients and Interruptions.

Characteristics, causes, effects and methods of mitigation. Voltage sag performance evaluations for transmission and distribution systems. Harmonics – Causes, effects, methods of quantitative analysis of voltage and current harmonics contamination in their respective waveforms. Harmonic Resonance – their causes, effects and mitigation. Effects of harmonics on different power system components. Definitions of various powers, power factor and other figures of merit under balanced, unbalanced and non-sinusoidal conditions

Unit 3: Theories of load compensation.

Introduction to custom power devices and their applications in power system. Detailed modelling, analysis and design aspects of custom power devices (DSTATCOM, DVR). Compensators to mitigate power quality related problems.

Unit 4: Power Supplies and Active Filters

Unity power factor rectifier, UPS: online and offline, power supplies in telecommunication system, High frequency induction heating, Dielectric heating, Power supplies in automobiles, Passive filters, active filter for harmonic and reactive power compensation in two wire, three wire and four wire ac systems. Harmonic standards, power quality, surge suppression, compensation of arc furnace and traction loads. Microwave ovens, light and temperature controllers, power supplies for appliances such as camera, X-Ray equipment

Text Books:

1. Math H. J. Bollen, Understanding Power Quality, IEEE Press
2. Roger C. Dugan et.al, Electrical Power Systems Quality, McGraw Hill
3. Arindam Ghosh and Gerard Ledwich, Power Quality Enhancement Using Custom Power Devices, Springer

Reference Books:

1. Reactive power control in electric systems, T. J. E. Miller, Wiley, 1982.
2. NPTEL Course on "Power Quality in Power Distribution Systems", Mahesh Kumar

Course Outcomes: At the end of this course, students are able to:

1. A**nalyse** the causes of different PQ problems in single and three phase circuits power conditions and components
2. Analyse fundamental theories of load compensation
3. Model and develop control technique of the compensator for load compensation
4. Realize the shunt and series compensator under unbalance and harmonic

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	3	3	2	2
CO 2	3	3	2	2
CO 3	3	3	2	2
CO 4	3	3	2	2

3- High, 2- Medium, 1-Low

	Intelligent Control Techniques	L	T	P	C
EE 5341	**M. Tech in Power Electronics and Drives** **Electrical Engineering Branch**	**3**	**0**	**0**	**3**

Pre-requisites: Control Systems

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Introduction

Approaches to intelligent control; Architecture for intelligent control; symbolic reasoning system; rule-based systems; AI approach; Knowledge representation; Expert systems, Machine Learning Basics, application in power electronics and drives.

Unit 2: Fuzzy Logic Control System

Motivation and basic definitions; Fuzzy arithmetic and Fuzzy relations; Fuzzy logic modeling and control; Fuzzy knowledge and rule bases; Fuzzy modeling and control schemes for nonlinear systems; Self-organizing fuzzy logic control; Fuzzy logic control for nonlinear time-delay system; Stabilization using fuzzy models; Fuzzy estimators; Adaptive fuzzy control. application in power electronics and drives

Unit 3: ANN based Controllers and Estimators

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; Data Processing: Scaling; Hopfield network; Self-organizing network and Recurrent network; Neural Network based controllers and estimators. application in power electronics and drives

Unit 4: Genetic Algorithm

Basic concept of Genetic algorithm and detail algorithmic steps; Adjustment of free parameters; Solution of typical control problems using genetic algorithm; Concept on some other search techniques like tabu search and ant-colony search techniques for solving optimization problems; Evolutionary Fuzzy logic controllers.

Unit 5: Case Studies

Identification and control of linear and nonlinear dynamic systems using MATLAB- Neural Network toolbox; Stability analysis of Neural-Network interconnection systems; Implementation of fuzzy logic controller using MATLAB fuzzy-logic toolbox; Stability analysis of fuzzy control systems, Intelligent control in power converter.

Text Books:

1. Padhy.N.P.; “Artificial Intelligence and Intelligent System”; Oxford University Press.
2. KOSKO, B. "Neural Networks and Fuzzy Systems"; Prentice-Hall of India Pvt. Ltd.
3. Jacek. M. Zurada; "Introduction to Artificial Neural Systems"; Jaico Publishing House.

Reference Book:

1. KLIR G.J. & FOLGER T.A. "Fuzzy sets; uncertainty and Information"; Prentice-Hall of India Pvt. Ltd.

Course Outcomes: After completing the course, the students will be able to:

1. Identify and describe soft computing techniques and their roles in building intelligent machines.
2. Apply fuzzy logic and reasoning to handle uncertainty and solve various engineering problems.
3. Apply genetic algorithms to combinatorial optimization problems.
4. Identify various tools to solve soft computing problems

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	3	3	2	1
CO 2	3	3	2	3
CO 3	3	3	2	3
CO 4	3	3	2	1

3- High, 2- Medium, 1-Low

	Energy Storage Systems	**L**	**T**	**P**	**C**
EE 5342	**M. Tech in Power Electronics and Drives**	**3**	**0**	**0**	**3**
	Electrical Engineering Branch				

Pre-requisites: Power Electronics

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Battery

Energy Storage Parameters; Lead–Acid Batteries- Constructional Features, Charge–Discharge Cycles, Operating Limits, Maintenance and Sizing, Types, Applications. Performance measurement, storage density, energy density, and safety issues in different types of batteries.

Unit 2: Ultracapacitors/Supercapacitors

Double-Layer Ultracapacitors, High-Energy Ultracapacitors, Rating, Size & Applications; Supercapacitors - Basic components, Types of electrodes and electrolytes, Advantages and Disadvantages, Comparison with battery systems, applications. Aspects of energy density, power density, price, and market.

Unit 3: Hydrogen Fuel Cells and Flow Batteries

Fuel cells for direct energy conversion, electrochemical energy converters, power outputs, Types of fuel cells, Hydrogen Economy and Generation Techniques, Storage of Hydrogen, Hybrid Energy Storage, Managing peak and Continuous power needs, options - Level 1: (Hybrid Power generation) Bacitor "Battery + Capacitor" Combinations: need, operation and Merits; Level 2: (Hybrid Power Generation) Bacitor + Fuel Cell or Flow Battery operation.

Unit 4: Flywheel and Other Storages

Pumped Hydroelectric Energy Storage, , Compressed Air Energy Storage, Storage Heat, Energy Storage as an Economic Resource. Flywheels**:** Advanced Performance of Flywheels, Design Strategies, Superconducting Magnetic Energy Storage (SMES) systems, SMES, Capabilities and Developments in SMES Systems

Unit 5: Power Electronics for Energy Storage Systems

Basic operation and modeling of power electronic converters applied in energy storage systems. analysis and design of power converter circuits such as AC-DC, DC-DC and DC-AC converters for energy storage systems, Applications: Storage for Hybrid Electric Vehicles.

Text Books:

1. DetlefStolten," Hydrogen and Fuel Cells: Fundamentals, Technologies and Applications", Wiley, 2010.

2. Jiujun Zhang, Lei Zhang,Hansan Liu, Andy Sun, Ru-Shi Liu, “Electrochemical Technologies for Energy Storage and Conversion”, John Wiley and Sons, 2012.
3. Francois Beguin and ElzbietaFrackowiak ,“Super capacitors”, Wiley, 2013.
4. Doughty Liaw, Narayan and Srinivasan, “Batteries for Renewable Energy Storage”, The Electrochemical Society, New Jersy,2010.

Reference Books:

1. M. Broussely, in Industrial Applications of Batteries. From Cars to Aerospace and Energy Storage’, M. Broussely and G. Pistoia, Eds., Elsevier, Amsterdam, 2007.
2. M. Broussely, in Industrial Applications of Batteries. From Cars to Aerospace and Energy Storage’, M. Broussely and G. Pistoia, Eds., Elsevier, Amsterdam, 2007.
3. M. Broussely, in Lithium Batteries – Science and Technology, G.A. Nazri and G. Pistoia,Eds., Kluwer Academic Publishers, Boston, USA, 2004.

Course Outcomes: After completing the course, the students will be able to:

1. Understand the different types of batteries and capacitors.
2. Relate different types of fuel cell, flywheel and other energy storage system
3. Articulate the suitable storage system for various power electronic systems.

CO-PO Mapping (Articulation Matrix)

CO\PO	PO1	PO2	PO3	PO4
CO1	3	2	1	1
CO2	3	1	2	1
CO3	3	2	2	2

3- High, 2- Medium, 1-Low

	Smart Grid and Distribution Automation	**L T P C**
EE 5343	**M. Tech in Power Electronics and Drives**	**3 0 0 3**
	Electrical Engineering Branch	

Pre-requisites: Power Electronics

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Smart Grid Structure

Definition, Difference between the conventional grid and smart grid, Various components, Smart Grid architecture, Application and standards, Distributed Generation.

Unit 2: Communication Technologies for Smart Grid

Data communication, -Dedicated and Shared communication channels, Wired and wireless communication channels, Power Line Communication, Layered architecture and Protocols.

Unit 3: Advanced Monitoring Infrastructure

Smart meters, Wide area monitoring system, Phasor measurement units, SCADA.

Unit 4: Distribution Automation

Introduction to Distribution Automation. Role of smart meter in distribution automation. Substation automation, feeder automation, customer level automation.

Unit 5: Demand Side Management

Definition, Impact analysis of DSM, load curve, Energy consumption scheduling, Load Management, Plug In Hybrid Electric Vehicles.

Unit 6: Microgrid Protection

Grid connected and Islanding mode of operations, passive and active islanding schemes, Protection issues of microgrid.

Unit 7: Interoperability & Cyber Security in Smart Grid

State of the art interoperability-Benefits and challenges of interoperability, Load Altering Attack (LAA), false data injection attack, Security issues with smart meters, possible solutions**.**

Text Books:

1. Smart Grid: Fundamentals of design and analysis by James Momoh (John Wiley & Sons publisher).
2. Smart Grid: Technology and applications by J. Ekanayake, N. Jenkins, K. Liyanage K, J. Wu, A. Yokoyama (Wiley publication).

Reference Books:

1. Power Generation Operation and Control by A. J. Wood, B. F. Wollenberg (John Wiley & Sons publisher).
2. James A. Momoh.," Electric Power Distribution, Automation, Protection, And Control", CRC Press, 2010.

Course Outcomes: At the end of this subject, students will be able to:

1. Understand the operation and intermittent nature of renewable energy sources.
2. Analyze smart grid structure including, technologies, components, measuring, standards used and applications.
3. Apply knowledge to develop demand side management strategy and inspect the cyber security issues.
4. Analyze the necessity of monitoring, control and automation of distribution system.

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	3	3	2	1
CO 2	3	3	2	2
CO 3	3	3	2	3
CO 4	3	3	3	1

3- High, 2- Medium, 1-Low

EE 5344	Multilevel and Multipulse Converters M. Tech in Power Electronics and Drives Electrical Engineering Branch	L T P C 3 0 0 3

Pre-requisites: Power Electronics

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: **Basics of Multilevel inverter and conventional topologies**

Basic concept of Multilevel inverter, Advantages and applications of MLIs, Conventional topologies: CHB Inverter and Modulation Strategies, Diode-Clamped Structure and Modulation Strategies, Flying Capacitor multilevel inverter Structure and Modulation Strategies, Issues With Conventional Topologies

Unit 2: Reduced device count multilevel inverters

Basic structure of Symmetrical, Asymmetrical, single DC source and transformer based multilevel inverter, Introduction of advent of new topologies for MLIs, MLI Topologies with reduced device count: T-Type Inverter, Switched Series/Parallel Sources–Based MLI, Series-Connected Switched Sources–Based, Cascaded "Bipolar Switches Cells"–Based MLi, Packed U-Cell Topology, and Multilevel Module–Based MLI, Recently developed topologies.

Unit 3: Modulation schemes for Multilevel Inverter

Modulation Strategies for MLIs, Description of the UCS, Implementation of UCS for a Five-Level Cascaded Multilevel inverter, Space vector modulation scheme for 5-level inverter and their limitations, Implementation of UCS in some recently proposed topologies, Recently developed modulation schemes for multilevel inverters.

Unit 4 : Applications, control and implementation of Multilevel Inverter Topologies

Multilevel inverter control for renewable energy systems, MLI and their control for grid connected inverter systems, Single stage and double stage multilevel inverter, MLI application in FACTS, drives and in shunt active filters with their control, Detailed study of Hardware components used to construct different multilevel inverter topologies.

Unit 5: Introduction to Harmonics, Multipulse Methods & Transformer

Harmonic requirements: Voltage Distortion, Current distortion, Telephone Interference, Definition Of terms. Power Source Representation: Effects of Negative Sequence Voltages, effects of pre-existing harmonic Voltages, Effects on Multipulse converters, Different Circuit Topologies, Multipulse Methods & Transformer: Multipulse Methods, Multipulse Transformer Basics: Determining Phase Shift, Discussion of Vector representation, transformer kVA Rating, Inductor kVA rating, Different Types of Multipulse Methods & Transformer

Text Books:

1. Krishna Kumar Gupta, Pallavee Bhatnagar, Multilevel Inverters, Academic Press, 2018, ISBN 9780128124482, https://doi.org/10.1016/B978-0-12-812448-2.00004-0.
2. Bin Wu, High Power Converters and AC Derives, IEEE Press, 2006.
3. Derek A. Paice, Power Electronic Converter Harmonics, Multipulse method for clear Power, IEEE Press.

Reference Books

1. N. Mohan, T. M. Undeland, et al., Power Electronics—Converters, Applications and Design, 3rd edition, John Wiley & Sons, New York, 2003.
2. GE Toshiba Automation Systems, A New Family of MV Drives for a New Century—DURA BILT 5i MV, Product Brochure, 50 pages, March 2003.

Course Outcomes: At the end of this subject, students will be able to:

1. Understand the structure of conventional Multilevel Inverter configurations.
2. Develop and design the reduced component Multilevel Inverter topologies.
3. Implement the modulation scheme to generate levels in Multilevel Inverters.
4. Study the recent applications and hardware study of Multilevel Inverters.
5. Evaluate the performance of different configuration of Multipulse Inverter

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	3	3	2	1
CO 2	3	3	2	2
CO 3	3	3	2	3
CO 4	3	3	3	1
CO 5	3	3	2	1

3- High, 2- Medium, 1-Low

EE 5311	**Modelling and Control of Electrical Machines** **M. Tech in Power Electronics and Drives** **Electrical Engineering Branch**	**L T P C** **3 0 0 3**

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid semester examination, surprise tests, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Elements of Generalized Theory

Essentials of Rotating Electrical Machines, Conventions, Basic Two-pole Machine, The Per Unit System, Transformer and Speed Voltages in the armature, Kron's Primitive Machine, Analysis of Electrical Machines. Invariance of Power, Transformation from Three Phases to Two phases (a, b, c to α, β, 0), Transformation from rotating axes to stationary axes, Physical concept of Park's Transformation.

Unit 2: Dynamic Modeling of Induction Motor Drives

Dynamic d-q model: power equivalence, generalized model in arbitrary reference frames, electromagnetic torque, commonly used induction motor models - stator reference frame model, rotor reference frame model, synchronously rotating reference frame model; equations in flux linkages, introduction to state space model.

Unit 3: Field Oriented Control of Induction Motor Drives

DC drive analogy-principles of vector control, vector control methods, direct vector control, indirect vector control, flux vector estimation, vector control of line-side PWM rectifier, stator flux oriented vector control, vector control of current-fed inverter drive and cycloconverter drives, speed-sensorless vector control, speed estimation methods, direct torque and flux control (DTC).

Unit 4: Modeling and Control of Synchronous Motor Drives

Dynamic modeling of synchronous motor, control strategies, open loop v/f, self-control, vector control: constant torque angle control, unity power factor control, constant mutual flux linkage control; flux weakening operation, implementation strategies, sensorless control.

Unit 5: Modeling and Control of BLDC, PMSM and SRM Motor Drives

Brushless DC (BLDC) motors- machine model and control methods; Permanent Magnet Synchronous Motors (PMSM) - machine model and control methods; Switched Reluctance Motor (SRM) - machine model and control methods.

Text Books:

1. P. S. Bimbhra. Generalized Theory of Electrical Machines. Khanna publications
2. P.C. Krause. Analysis of Electric Machinery, McGraw Hill, New York.
3. B. K. Bose. Modern Power Electronics and AC drives. Pearson publications

4. R. Krishnan. Electric motor drives Modeling, Analysis. Pearson Publications.

Reference Books:

5. C.V. Jones. The Unified Theory of Electrical Machines Butterworth, London, 1967
6. J.M.D. Murphy & F.G. Turnbull. Power Electronic Control of AC motors, Pergamon Press
7. P. VAS. Vector control of AC machines. Clarendon Press, Oxford
8. B.K. Bose. Power Electronics and Variable frequency drives. IEEE Press Standard publications, 1st Edn.

Course Outcomes (Cos):

At the end of the course the students will be able to

1. Develop generalized model of AC machines.
2. Analyze the field-oriented control strategies for induction motor drives.
3. Analyze the field-oriented control strategies for synchronous motor drives.
4. Evaluate the performance of induction and synchronous motor drives.

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	2	2	2	2
CO 2	2	2	2	2
CO 3	2	2	2	2
CO 4	2	2	2	1

3- High, 2- Medium, 1-Low

	Grid Connected Power Converters	**L**	**T**	**P**	**C**
EE 5312	**M. Tech in Power Electronics and Drives**	**3**	**0**	**0**	**3**
	Electrical Engineering Branch				

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid semester examination, surprise tests, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Overview of power electronic converters for utility applications

Introduction to the Grid connected Converter for utility applications, International Standards, Response to Abnormal Grid Conditions: Voltage Deviations, Frequency Deviations, and Reconnection after Trip**.** Power Quality: DC Current Injection, Current Harmonics, Average Power Factor. Anti-islanding (AI) requirement, ride through capability, AI Defined by IEEE 1547/UL 1741, AI Defined by IEC 62116, AI Defined by VDE 0126-1-1.

Unit 2: Grid-connected Inverter for PV and wind system

Background, Generalized Photovoltaic power conversion and its control, Power Conversion topologies: Module converters, String inverter topologies, Centralized inverters, High-voltage and high-power converters; Inverter Structures Derived from H-Bridge Topology, Three-Phase PV Inverters, WTS Power Configurations, Grid Power Converter Topologies: Single-Cell (VSC or CSC), Multicell (Interleaved or Cascaded), WTS Control Generator and Grid Side Control

Unit 3: Grid synchronization of single and three-phase inverters

Grid Synchronization Techniques for Single-Phase Systems: Grid Synchronization Using the Fourier Analysis, Grid Synchronization Using a Phase-Locked Loop, Phase Detection Based on In-Quadrature Signals: PLLs Based on In-Quadrature Signal Generation: Transport Delay, Hilbert Transform, Inverse Park Transform, The Enhanced PLL, Generalized Integrator; The SOGI-PLL Grid Synchronization in Three-Phase Power Converters, The Synchronous Reference Frame PLL under Unbalanced and Distorted Grid Conditions, The Double Second-Order Generalized Integrator FLL (DSOGI-FLL).

Unit 4: Control of Grid Converters under Grid Faults

Overview of Control Techniques for Grid-Connected Converters under unbalanced Grid Voltage Conditions, Control Structures for Unbalanced Current Injection, Power Control under Unbalanced Grid Conditions.

Unit 5: Current Control and filter design

Current Harmonic Requirements, PWM current control methods, Linear Current Control with Separated Modulation: Use of Averaging, PI-Based Control, Deadbeat Control, Resonant Control, Harmonic Compensation, Practical Examples Filter design: Filter Topologies, Design Considerations, Practical Examples of LCL Filters and Grid Interactions.

Text Books:

1. Remus Teodorescu, Marco Liserre, Pedro Rodríguez, Frede Blaabjerg, 'Grid Converters for Photovoltaic and Wind Power Systems', John Wiley & Sons, 2011.
2. Amirnaser Yazdani and Reza Iravani, 'Voltage Source Converters in Power systems: Modeling, Control, and Applications', John Wiley & Sons, 2010.

Reference Books:

1. Nick Jenkins, Ron Allan, Peter Crossley, Daniel Kirschen and Goran Strbac, 'Embedded Generation',IET,2000.
2. Ali Keyhani, Mohammad N. Marwali, Min Dai, 'Integration of Green and Renewable Energy in Electric Power Systems', John Wiley & Sons, 2010.
3. S. Chowdhury, S.P. Chowdhury and P. Crossley, 'Microgrids and Active Distribution Networks', IET,2009.
4. Ryszard Strzelecki & Grzegorz Benysek, "Power Electronics in Smart Electrical Energy Networks", Springer, 2008.

Course Outcomes: At the end of the course the students will be able to

1. Analyze the importance of power electronics converter for utility
2. Evaluate topologies of the grid connected inverter structures
3. Select suitable synchronizing techniques for single and three phase inverters
4. Design the control techniques for grid connected inverters

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO1	2	2	2	1
CO2	3	3	3	2
CO3	2	2	2	1
CO4	3	3	3	3

3- High, 2- Medium, 1-Low

EE 5313	Pulse Width Modulations for Power Converters M. Tech in Power Electronics and Drives Electrical Engineering Branch	L T P C 3 0 0 3

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid semester examination, surprise tests, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Power Electronic Converters

Introduction to PE converters - AC/DC and DC/AC power conversion, overview of applications of voltage source converters, pulse modulation techniques for bridge converters, Modulation of one inverter phase leg, Modulation of single phase, VSI and 3-phase VSI, symmetrical PWM (single and equal pulse width modulation), selective harmonic elimination technique, sinusoidal PWM, sequence control with forced commutation; Unity Power Factor Converters (single-phase and three-phase).

Unit 2: Space Vector Modulation Strategies, Modulation of CSI

Space vector based modulation, space vector based PWM, Bus clamping PWM, advanced PWM techniques, Zero space vector placement modulation strategies, practical devices in converter; calculation of switching and conduction losses, Discontinuous modulation of CSI.

Unit 3: Modulation of Converters

Over modulation of converters, Per-phase and space vector approaches to overmodulation, average voltages in a synchronously revolving d-q reference frame, low-frequency harmonic distortion, programmed modulation strategies, dynamic model of a PWM converter.

Unit 4: PWM for Multilevel Inverters

Pulse width modulation for multilevel inverters, Extensions of sine-triangle PWM to multilevel inverters, Extension of conventional space vector modulation to three-level to multilevel inverters, Implementation of modulation controller.

Module 5: Advanced PWM Modulation

Continuing developments in modulation as random PWM, PWM for voltage unbalance. Effect of minimum pulse width and dead time.

Text Books:

1. D. Grahame Holmes, Thomas A. Lipo, “Pulse width modulation of Power Converter: Principles and Practice”, John Wiley & Sons, 03-Oct-2003.
2. Bin Vew, “High Power Converter”, Wiley Publication.

Reference Book:

1. Marian K. Kazimicrczuk, “Pulse width modulated dc-dc power converter”, Wiley Publication.

Course Outcomes: At the end of the course the students will be able to

1. Understand the importance of PWM techniques.
2. Implement PWM using different strategies.
3. Analyze the control of CSI and VSI using PWM.
4. Compare the performance of a converter under different PWM techniques.

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	3	3	2	1
CO 2	3	3	2	2
CO 3	3	3	2	1
CO 4	3	3	2	1

3- High, 2- Medium, 1-Low

EE 5314	Energy Conversions and Drives Laboratory M. Tech in Power Electronics and Drives Electrical Engineering Branch	L	T	P	C
		0	0	3	2

Course Assessment methods (both continuous and semester end assessment): It may be practical sessions with coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

List of experiments

1. Modeling of Solar PV System using MATLAB software.
2. Effect of Temperature, irradiation, shading and load on Solar Panel Output.
3. Modeling of a grid connected/standalone wind generator system using MATLAB software.
4. Obtain the Power Vs Wind Velocity Curve of a Wind Turbine.
5. Build a Wind Farm using wind generators using MATLAB software.
6. Test the Capabilities of Solar Panels and Wind Turbines under different operating conditions (irradiation; wind velocity, grid distortions etc.).
7. Modeling and control of a Battery Energy Management System.
8. Modeling and testing of a Microgrid.
9. Test the Capabilities of the Hydrogen Fuel Cells and Capacitors.
10. Modeling and testing of EVs.

Course Outcomes: At the end of the course the students will be able to

1. Model and Design a Solar PV System.
2. Model a grid connected or isolated Wind Generator.
3. Testing of Solar PV System and Wind Generators under various operating conditions.
4. Model and understand the operation of a Battery Energy Management System
5. Understand and model a basic EV.

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	3	3	3	3
CO 2	3	3	3	3
CO 3	3	3	3	3
CO 4	3	3	3	3
CO 5	3	3	3	3

3- High, 2- Medium, 1-Low

EE 5315 **SEMINAR II** **L T P C**

M. Tech in Power Electronics and Drives

Second Semester **0 0 2 1**

Course Outcome of Seminar:

At the end of seminar course, students will be able to:

(1) Prepare good slides and present a particular topic effectively.
(2) Develop team spirit and leadership qualities through group activities.
(3) Develop confidence for self-learning and overcome the fear of public presentations.
(4) Update knowledge on contemporary issues, prepare technical report and do presentations on these issues.
(5) Learn technical editing software Latex and write technical report using LaTeX.

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	3	3	3	3
CO 2	3	3	3	3
CO 3	3	3	3	3
CO 4	3	3	3	3
CO 5	3	3	3	3

3- High, 2- Medium, 1-Low

EE 5360	**Electric and Hybrid Electric Vehicles** **M. Tech in Power Electronics and Drives** **Electrical Engineering Branch**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**

Pre-requisites: Power Electronics

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: EV Fundamentals

Vehicle Basics, Vehicle Resistance, Dynamic Equation Tire–Ground Adhesion and Maximum Tractive Effort, Power Train Tractive Effort and Vehicle Speed; Hybridization of the Automobile: Basics of the HEV, Basics of Plug-In Hybrid Electric Vehicle (PHEV) and vehicle architectures: Series Hybrid Vehicle, Parallel Hybrid Vehicle, Basics of Fuel Cell Vehicles (FCVs).

Unit 2: Power Electronics in EVs

Power electronics circuits used for control and distribution of electric power in DC-DC, AC-DC, DC-AC converters used for HEV. Electric Machines and Drives in HEVs: Fundamental of Drives and Control of EV Using DC motor, Induction Motor, Permanent Magnet Motor, Switched Reluctance Motor, BLDC motor, Design and Sizing of Traction Motors.

Unit 3: Batteries, Ultracapacitor, Fuel Cells, and Controls

Introduction, Different batteries for EV, Battery Characterization, Comparison of Different Energy Storage Technologies for HEVs, Battery Charging Control, Charge Management of Storage Devices, Flywheel Energy Storage System, Fuel Cells and Hybrid Fuel Cell Energy Storage System and Battery Management System.

Unit 4: EV Charging Technologies

Classification of different charging technology for EV charging station, introduction to Grid-to-Vehicle, Vehicle to Grid (V2G) or Vehicle to Buildings (V2B) or Vehicle to Home (V2H) operations, Bi-directional EV charging systems, Energy management strategies used in hybrid and electric vehicle, Wireless power transfer (WPT) technique for EV charging.

Textbooks:

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

Reference Books:

1. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003

2. Chris Mi, M. Abul Masrur, David Wenzhong Gao, Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives, John Wiley & Sons Ltd., 2011

Course Outcomes: At the end of the course the students will be able to

1. Apprehend the basics of electric and hybrid electric vehicles, their architecture, technologies and fundamentals.
2. Analyze the use of different power electronics converters and electrical machines in hybrid electric vehicles.
3. Select proper energy storage systems used for hybrid electric vehicles
4. Analyze different charging/discharging configurations of EV’s

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO1	2	2	1	2
CO2	3	3	2	1
CO3	2	2	1	2
CO4	3	3	3	1

3- High, 2- Medium, 1-Low

	AC/DC Microgrids	**L T P C**
EE 5361	**M. Tech in Power Electronics and Drives**	**3 0 0 3**
	Electrical Engineering Branch	

Pre-requisites: Power Electronics

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Introduction and architecture of microgrids

Conventional power generation: advantages and disadvantages, Energy crises, Non - conventional energy (NCE) resources, Concept of distributed generations, Standards for interconnecting Distributed resources to electric power systems: IEEE 1547. Definition of microgrid, typical microgrid configurations: AC and DC micro grids, interconnection of microgrids, technical and economic advantages of microgrid, components of microgrid, distributed energy resources (DER): DER interface, storage systems; batteries, flywheels, ultracapacitors

Unit 2: Power quality issues and communication requirement in Microgrid

Power quality issues in microgrids- Modelling and Stability analysis of Microgrid, regulatory standards, Microgrid economics, Introduction to smart microgrids

Communication Infrastructure: Requirement of Communication System in microgrids, Communication protocols and standards; Selection of communication protocols for microgrids. Event triggered system and Time triggered system, Unicast and Multicast Communication, Impact of time latencies on operation

Unit 3: DC microgrid

Advantages of dc microgrids and applications, energy resources in dc microgrids, hierarchical power sharing, droop control, centralized control, decentralized control, tertiary control, control of the power electronics converters in autonomous dc microgrids, protection system

Unit 4: AC microgrid

Master-slave architecture, control strategy for power electronics converter, grid-connected operation: active and reactive power control, power quality issues in microgrids, requirements for grid interconnection, response to grid abnormal conditions, islanded operation and issues, protection system, hybrid ac-dc microgrid, battery energy management systems, Supervisory Control for AC Microgrid, Virtual Inertia Control

Unit 5: Demand side management and cyber security issues

Customers category, incentive-based demand response, cooperative power microgrid, Introduction to cyber attacks, active detection of cyber attacks

Text Books:

1. Magdi S. Mahmoud. Microgrid- Advanced Control Methods and Renewable Energy System Integration. Butterworth-Heinemann (Elsevier)
2. Nikos Hatziargyriou. Microgrids Architectures and Control. Wiley

Reference Books:

1. Remus Teodorescu, Marco Liserre, Pedro Rodriguez. Grid Converters for Photovoltaic and Wind Power Systems. Wiley Publications
2. Suleiman M. Sharkh. Power Electronic Converters for Microgrids. Wiley

Course Outcomes: At the end of the course the students will be able to

1. Examine the architectures of DC/AC microgrid.
2. Evaluate various power quality issues and communication issues for micro grid operation.
3. Analyze different control strategies for DC and AC microgrids.
4. Interpret demand response in a microgrid and cyber security

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO1	2	2	1	1
CO2	3	3	2	1
CO3	2	2	1	2
CO4	3	3	3	3

3- High, 2- Medium, 1-Low

EE 5362	Low Voltage Power Electronics M. Tech in Power Electronics and Drives Electrical Engineering Branch	L T P C 3 0 0 3

Pre-requisites: Power Electronics, Electronic Devices and Circuits, Basic Electronics.

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid semester examination, surprise tests, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Fundamental concepts of power management

Background, Renewable Energy Harvesting – solar energy harvesting – thermal energy harvesting – other energy harvesting. Power management. DC-DC power converters – linear regulators – switch mode power converters – switched capacitor power converters. Switched capacitor converter design – advanced multiphasing. The dramatic increase in power – Low-Power Workshops – Low-Power Design Techniques

Unit 2: Basics and Design of Charge pump topologies

Principle of charge transfer. Charge pump parameters. Fundamental charge pump and topologies – voltage inverter – voltage doubler – step-up and step-up charge pump. Practical charge pump design – Dickson charge pump – cross coupled voltage doubler. IC Design – practical capacitor implementation – MOSFET transistor as switches. Fully Integrated Switched-Capacitor Fundamentals – working Principle – charging and sharing losses – topology. Modelling – extrinsic loss analysis and impedance. Optimization – converter topology, and voltage dependent devices.

Unit 3: Switched Capacitor Converter for Low Power Design

Fundamental and principles of switched capacitor converter. Topologies and control strategies. Regulation techniques – interleaving regulation – cross couple voltage doubler – master slave SC converter – hybrid SC converter. Design of SC power converters – SC converter for low voltage and low power. MIMO switched-capacitor converter using parasitic coupling – principle, characterization, and regulation.

Unit 4: Switched Capacitor Design and Modelling in Z domain

Basics of Z domain. Cross-Coupled SC Voltage doubler design in z-Domain. SC power converter for ultra-low power applications. Adaptive Step-down SC Power Converter. Voltage domain analysis – A new analysis tool – two phase and multiphase converter.

Text Books:

1. Reconfigurable Switched-Capacitor Power Converters, Dongsheng Ma, Rajdeep Bondade, Vol. 9. Springer, 2003.
2. Advanced Multiphasing Switched-Capacitor DC-DC Converters, Nicolas Butzen, Michiel Steyaert, Vol. 15. Springer, 2020.

Reference Books:

1. Low-Power Electronics Design (Computer Engineering Series), Christian Piguet, 1st edition, CRC press, 2004.

Course Outcomes: At the end of this course, students will be able to:

1. Understand the fundamental concepts of low power management devices.
2. Design of charge pump converter and practical capacitor implementation.
3. Analyze of switched capacitor converters for low power applications
4. Model switched capacitor converter topologies.

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO1	2	2	1	2
CO2	3	3	2	3
CO3	2	2	1	2
CO4	3	3	3	2

3- High, 2- Medium, 1-Low

	Special Electromechanical Systems	**L**	**T**	**P**	**C**
EE 5363	**M. Tech in Power Electronics and Drives**	**3**	**0**	**0**	**3**
	Electrical Engineering Branch				

Pre-requisites: Electrical Machines, Power Electronics

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Wound Rotor Induction Generators (WRIGs)

Steady-State Equations, Equivalent Circuit, Phasor Diagrams, Grid Connected Operation of WRIG, Autonomous Operation of WRIG, Operation of WRIG in the Brushless Exciter Mode, Losses and Efficiency of WRIG, Testing of WRIGs.

Unit 2: Self-Excited Induction Generators

Cage Rotor Induction Machine Principle, Self-Excitation: A Qualitative View, Steady-State Performance of Three-Phase SEIGs, Second-Order Slip Equation Methods, SEIGs with Series Capacitance Compensation, Performance Sensitivity Analysis, Fixed Speed SEIGs, Pole Changing SEIGs for Variable Speed Operation, Unbalanced Operation of Three-Phase SEIGs, Parallel Connection of SEIGs, Connection Transients in Cage Rotor Induction Generators at Power Grid.

Unit 3: Squirrel Cage Induction Generators (SCIGs)

Grid Connected SCIGs: Machine-Side PWM Converter Control, Grid-Side Converter Control, Grid Connection and Four-Quadrant Operation of SCIGs, Stand-Alone Operation of SCIG, Parallel Operation of SCIGs, Static Capacitor Exciter Stand-Alone IG for Pumping Systems, Operation of SCIGs with DC Voltage Controlled Output, Dual Stator Winding for Grid Applications.

Unit 4: Induction Starter/Alternators (ISAs) for Electric Hybrid Vehicles (EHVs): EHV Configuration, Essential Specifications Peak, Torque (Motoring) and Power (Generating) , Battery Parameters and Characteristics, Topology Aspects of Induction Starter/Alternator (ISA), ISA Space-Phasor Model and Characteristics, Vector Control of ISA, DTFC of ISA, ISA Design Issues for Variable Speed, Power and Voltage Derating, Increasing Efficiency, Increasing the Breakdown Torque, Additional Measures for Wide Constant Power Range.

Unit 5: Switched Reluctance Generators

Practical Topologies and Principles of Operation, The kW/Peak kVA Ratio, SRG(M) Modeling, The Flux/Current/Position Curves, Design Issues, Motor and Generator Specifications, PWM Converters for SRGs, Control of SRG(M)s, Feed-Forward Torque Control of SRG(M) with Position Feedback, Direct Torque Control of SRG(M), Rotor Position and Speed Observers for Motion-Sensorless Control, Output Voltage Control in SRG.

Unit 6: Permanent Magnet Synchronous Generator Systems

Practical Configurations and Circuit Model, The Phase Coordinate Model, The d–q Model of PMSG, Circuit Model of PMSG with Shunt Capacitors and AC Load, Circuit Model of PMSG with Diode Rectifier Load, Utilization of Third Harmonic for PMSG with Diode Rectifiers, Autonomous PMSGs with Controlled Constant Speed and AC Load, Grid-Connected Variable-Speed PMSG System, Design Issues: Rotor Sizing, Stator Sizing, The Losses, Super-High-Speed PM Generators.

Unit 7: Transverse Flux and Flux Reversal Permanent Magnet Generator Systems

Three-Phase Transverse Flux Machine (TFM), Magnetic Circuit Design, TFM — the d–q Model and Steady State; Three-Phase Flux Reversal Permanent Magnet Generator: Magnetic and Electric Circuit Design, FEM Analysis of Pole-PM FRM at No Load, FEM Analysis at Steady State on Load, Circuit Model of FRM, The d–q Model of FRM.

Text Books:

1. Fitzerald, Kinglay, Umans "Electrical Machniary", Tata Mc Graw Hill, 2004.
2. Rakosh Das Begamudre "Electromechanical Energy Conversation with Dynamics of Machines", New Age International, 2003.
3. Hughes, A. (1994). Electric Motors and Drives. Newnes.

Reference Books:

1. Leonhard,W. (1990). Control of Electrical Drives. Springer-Verlag, Berlin Heidelberg New York, Tokyo, 2 Edition.

Course Outcomes: At the end of this course, students will be able to:

1. Understand the operation of Induction and Synchronous Generators.
2. Model Induction and Synchronous Generators for specific applications.
3. Analyse the steady state performance of Induction and Synchronous Generators.
4. Select a specific generator configuration based on the application.

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO1	2	2	1	1
CO2	3	3	2	2
CO3	3	3	2	2
CO4	3	3	2	3

3- High, 2- Medium, 1-Low

	Modern Control Theory	**L**	**T**	**P**	**C**
EE 5364	**M. Tech in Power Electronics and Drives**	**3**	**0**	**0**	**3**
	Electrical Engineering Branch				

Pre-requisites: Control System, Electrical Machines

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Discrete Time Systems

Z-Transform Method, Sampled Data Control Systems, Digital Controller, Sample and Hold Operation, Frequency consideration in Sampling and Reconstruction, Z-transformation, Solution of Differential & State Equations by 'Z' Transform Method, The Inverse Z-Transform, Pulse Transfer Function and Stability in Zplane.

Unit 2: Space model specification

Transform Design of Digital Controls & State Space Concepts: Design Specifications, Design on the 'W'-plane, 'W plane & 'Z' plane. The Cayley Hamilton Theorem, Concepts of Controllability and Observability.

Unit 3: Stability

Generalized Stability Criterion (d-partition technique), Pole Assignment method, Lyapunov's method, Lure's transformation, Popov's criterion, introduction to stochastic process

Unit 4: Microprocessor Based Control Systems

Digital Quantization, Positional Control System, Temperature Control System, Stepper Motor Drive circuits and Control of a Manipulator Arm.

Unit 5: Optimization

Time Optimal System (without proof of control law), Calculation of switching trajectories for second order systems. Optimal control System based on quadratic performance indices (proof through Lyapunov's function), basic concepts of Model Reference Control System and Adaptive System. Pontryagin's maximum principle, constrained and unconstrained input, Dynamic Programming, optimality principle, Discrete and Continuous Dynamic Programming.

Text Books:

1. Thomas Kailath, Linear Systems, the University of Michigan, Prentice-Hall.
2. M. Gopal, Digital control, and state variable methods: conventional and intelligent control systems, Tata McGraw hill education private limited, New Delhi.
3. K. Ogata, Modern Control Engineering, Automatic control, Prentice Hall.

4. F. Lin, Robust Control Design: An Optimal Control Approach, John Willey & Sons ltd, USA

Reference Books

1. Linear Algebra and Its Applications. Gilbert Strang,
2. P. N. Paraskevopoulos, Modern Control Engineering, Marcel Dekker, New York,

Course Outcomes: At the end of the course the students will be able to:

1. Understand the various discrete time systems.
2. Analyze the digital control and state space model concept.
3. Examine the stability of the system and apply the concept for various application

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	2	2	1	1
CO 2	3	3	2	2
CO 3	3	3	2	2

3- High, 2- Medium, 1-Low

EE 5380	**Advanced Topics on Power Electronic Converters** **M. Tech in Power Electronics and Drives** **Electrical Engineering Branch**	**L T P C** **3 0 0 3**

Pre-requisites: Power Electronics

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Multiple-Quadrant Choppers

Multiple-Quadrant Operation, Pump Circuits- Fundamental Pumps- Buck Pump, Boost Pump, Buck-Boost Pump, Developed Pumps, Positive Luo-Pump, Negative Luo-Pump, Cúk-Pump, Transformer-Type Pumps-Forward Pump, Fly-Back Pump, ZETA Pump, Positive Push-Pull Pump, Negative Push-Pull Pump, Double/Enhanced Circuit (DEC), Development of DC/DC Conversion Technique.

Unit 2: Voltage-Lift Converters

Self-Lift Cúk Converter, Self-Lift P/O Luo-Converter, Reverse Self-Lift P/O Luo-Converter, Self-Lift N/O Luo-Converter, Reverse Self-Lift N/O Luo-Converter, Self-Lift SEPIC, Enhanced Self-Lift P/O Luo-Converter, Positive Output Luo-Converters, Variations of Currents and Voltages, Instantaneous Values of Currents and Voltages.

Unit 3: Cascade Boost Converters

Boost Circuit, Two-Stage Boost Circuit, Three-Stage Boost Circuit, Higher Stage Boost Circuit, Additional Series- Elementary Boost Additional (Double) Circuit, Two-Stage Boost Additional Circuit, Three-Stage Boost Additional Circuit, Higher Stage Boost Additional Circuit, Double Series- Elementary Double Boost Circuit, Two-Stage Double Boost Circuit, Three-Stage Double Boost Circuit, Higher Stage Double Boost Circuit, Triple Series- Elementary Triple Boost Circuit, Two-Stage Triple Boost Circuit

Unit 4: Multiple-Lift Push-Pull Switched-Capacitor Converters

Re-Lift Circuit, Triple-Lift Circuit, Higher Order Lift Circuit, Additional Series-Elementary Additional Circuit, Re-Lift Additional Circuit, Triple-Lift Additional Circuit, Higher Order Lift Additional Circuit, Enhanced Series, Multiple- Enhanced Series, Theoretical Analysis, Positive and Negative output Multiple-Lift Push-Pull Switched-Capacitor Converters, Integrated Switch Mode Power Converters.

Unit 5: Multiple-Quadrant Soft-Switch Converters & Synchronous Rectifier

Multiple-Quadrant DC/DC ZCS Quasi-Resonant Converters, Multiple-Quadrant DC/DC ZVS Quasi Resonant Converter, Multiple-Quadrant Zero-Transition DC/DC Converters, Design Considerations, Flat Transformer Synchronous Rectifier Luo-Converter, Active Clamped Synchronous Rectifier Converter, Double Current Synchronous Rectifier Converter, Zero-

Current-Switching Synchronous Rectifier Converter, Zero-Voltage-Switching Synchronous Rectifier Converter

Text Book:

1. Fang Lin Luo & Hong Ye, 'Advanced DC/DC Converters', CRC Press, 2004

Reference Book:

1. Ali Emadi, Alireza Khaligh, Zhong Nie & Young Joo Lee, 'Integrated Power Electronic Converters and Digital Control', CRC Press, 2009

Course Outcomes: At the end of this course, students will be able to:

1. Apprehend multiple quadrant and voltage lift Luo converters.
2. Analyze cascaded boost circuit and switched capacitor circuit
3. Analyze multi- quadrant soft switched converter

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO1	2	2	1	2
CO2	3	3	2	2
CO3	3	3	2	2

3- High, 2- Medium, 1-Low

	Electric Traction and Control	L T P C
EE 5381	M. Tech in Power Electronics and Drives	3 0 0 3
	Electrical Engineering Branch	

Pre-requisites: Power Electronics

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Traction Systems and Latest Trends

Present scenario of Indian Railways – High speed traction, Metro, Latest trends in traction-Metro, monorail, Magnetic levitation Vehicle, Steam, diesel, diesel-electric, Battery and electric traction systems, General arrangement of D.C. A.C. single phase,3phasehase,Composite systems, Choice of traction system - Diesel- Electric or Electric

Unit 2: Mechanics of Train Movement

Analysis of speed time curves for main line, suburban and urban services, Simplified speed time curves. Relationship between principal quantities in speed time curves, Requirement of tractive effort, Specific energy consumption and Factors affecting it.

Unit 3: Traction Motors and Their Control

Features of traction motors., Significance of D.C. series motor as traction motor, A. C. Traction motors-single phase, three phase, Linear Induction Motor, Comparison between different traction motors, Series-parallel control, Open circuit, Shunt and bridge transition, Pulse Width Modulation control of induction motors, Types of electric braking system.

Unit 4: Electric Locomotives and Auxiliary Equipment

Important features of electric locomotives, Different types of locomotives, Current collecting equipment, Coach wiring and lighting devices, Power conversion and transmission systems, Control and auxiliary equipment.

Unit 5: Feeding and Distribution System

Distribution systems pertaining to traction (distributions and feeders), Traction sub-station requirements and selection, Method of feeding the traction sub- station

Text Books:

1. Modern Electric Tractio,H. Partab Dhanpat Rai and Sons, New Delhi
2. Electric Traction, J. Upadhyay S. N. Mahendra Allied Publishers Ltd., Dhanpat Rai and Sons, New

Reference Books:

1. Electric Traction, A.T. Dover Mac millan, Dhanpat Rai and Sons, New Delhi
2. Electric Traction Hand Book, R. B. Brooks, Sir Isaac Pitman and sons ltd. London

Course Outcome: At the end of this course, students will be able to:

1. Distinguish different traction systems and latest trends in traction systems.
2. Differentiate services of traction system based on speed time curve.
3. Control different types of traction motors
4. Identify various traction system auxiliaries.
5. Explain the distribution system of a traction system.

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	2	2	1	1
CO 2	3	3	1	1
CO 4	3	3	1	1
CO 5	3	3	2	2

3- High, 2- Medium, 1-Low

	Digital Controller for Power Electronic Converters	**L**	**T**	**P**	**C**
EE 5382	**M. Tech in Power Electronics and Drives**	**3**	**0**	**0**	**3**
	Electrical Engineering Branch				

Pre-requisites: Power Electronics

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Types of microprocessor, RISC and CISC processor, Review of digital processors, Architecture of DSP, Fixed- and floating-point processors and microcontrollers. Number formats and operations, Assemblers and assembly and high language programming, Binary file formats, Mapping of s-domain to Z domain

Unit 2: Introduction to digital control application to power electronic circuits; Digital current mode control; Basic digital current control implementation; digital voltage mode control. Introduction to the C2xx DSP core and code generation, the components of the C2xx DSP core, Mapping external devices to the C2xx core

Unit 3: Pin Multiplexing (MUX) And General Purpose I/O Overview; Multiplexing and General Purpose I/O Control Registers; Introduction to Interrupts; Interrupt Hierarchy; Interrupt Control Registers; Initializing and Servicing Interrupts in Software.

Unit 4: ADC Overview; Operation of ADC in The DSP; Overview of The Event Manager (EV); Event Manager Interrupts; General Purpose (GP) Timers; Compare Units; Capture Units and Quadrature Enclosed Pulse (QEP) Circuitry; General Event Manager Information.

Unit 5: Application of DSP/FPGA for Controlled Rectifier; Switched Mode Power Converters; PWM Inverters; DC Motor Control; Induction Motor Control.

Text Books:

1. Simono Buso, Paolo Mattavelli," Digital control in Power Electronics", Morgan & Claypool Publisher.
2. Hamid.A.Toliyat and Steven.G.Campbel "DSP Based Electro Mechanical Motion Control" CRC Press New York, 2004.

Reference Books:

1. XC 3000 Series datasheets (Version 3.1). Xilinx, Inc., USA, 1998.
2. XC 4000 Series datasheets (Version 1.6). Xilinx, Inc., USA, 1999.
3. Wayne Wolf, "FPGA based System Design", Prentice Hall, 2000.

Course Outcome: At the end of this course, students will be able to:

1. Analyze the roles of I/Os, interrupts and control registers in digital control.
2. Select Field Programmable Gate Arrays based on the requirement.

3. Apply digital control for the control of power converters in motor control.

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	3	2	1	2
CO 2	3	3	1	3
CO 3	3	3	2	3

3- High, 2- Medium, 1-Low

EE 5383	**Energy Efficiency, Auditing and Loss Reduction** **M. Tech in Power Electronics and Drives** **Electrical Engineering Branch**	**L T P C** **3 0 0 3**

Pre-requisites: Power Electronics

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Electrical system & Electric Motors

Electricity billing, electrical load management and maximum demand control, power factor improvement and its benefit, selection and location of capacitors, performance assessment of PF capacitors, distribution and transformer losses. Electric motors: Types, losses in induction motors, motor efficiency, factors affecting motor performance, rewinding and motor replacement issues, energy saving opportunities with energy efficient motors.

Unit 2: Compressed Air System

Types of air compressors, compressor efficiency, efficient compressor operation, Compressed air system components, capacity assessment and leakage test, factors affecting the performance and savings opportunities.

Unit 3: Fans and Blowers

Types, performance evaluation, efficient system operation, flow control strategies and energy conservation opportunities. Pumps and Pumping System- Types, performance evaluation, efficient system operation, flow control strategies and energy conservation opportunities. Cooling Tower and Energy Efficient Technologies- Types and performance evaluation, efficient system operation, flow control strategies and energy saving opportunities assessment of cooling towers Different types of Energy Efficient Technologies.

Unit 4: Energy AUDIT

Understanding energy costs, Bench marking, Energy performance, Matching energy use to requirement, maximizing system efficiencies, Optimizing the input energy requirements, Fuel and energy substitution, Energy audit instruments.

Unit 5: Loss Reduction

Losses, Techniques, Advantages of loss reduction.

Text Book:

1. Energy management handbook, John Wiley and Sons - Wayne C. Turner

Reference Books:

1. Guide to Energy Management, Cape Hart, Turner and Kennedy.
2. Cleaner Production – Energy Efficiency Manual for GERIAP, UNEP, Bangkok prepared by National Productivity Council.

Course Outcome: At the end of this course, students will be able to:

1. Understand the basics of energy efficiency in different electrical systems.
2. Analyze compressed air systems and pumping systems.
3. Examine the energy audit and various loss reduction techniques.

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	2	2	1	1
CO 2	3	3	2	2
CO 3	3	3	2	2

3- High, 2- Medium, 1-Low

	Thermal, Thermoelectric and EMI/EMC Consideration in System Design	L	T	P	C
EE 5384	M. Tech in Power Electronics and Drives Electrical Engineering Branch	3	0	0	3

Pre-requisites: Power Electronics

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Unit 1: Heat Sinks: Longitudinal Fin of Rectangular Profile, Heat Transfer from Fin, Force Convection Cooling- Small Spacing Channel, Large Spacing Channel, Multiple Fin Array for Natural (Free) Convection Cooling, Thermal Resistance and Overall Surface efficiency, Fin Design with Thermal Radiation, Thermal modeling and simulation of parameters related to the semiconductor switching device.

Unit 2: Thermoelectric: Thermoelectric Effect, Thomson Relationships, Thermoelectric Generator (TEG), maximum Power Efficiency, multicouple Modules, Thermoelectric Coolers (TEC)- Coefficient of Performance, optimum Current For the Maximum Cooling Rate, Maximum Performance Parameters, Generalized Charts, Optimum Geometry for the Maximum Cooling in Similar Materials, Thermoelectric Modules/Design, Thermoelectric Generators, Thermoelectric Coolers, Thermoelectric Module Design, Thermal and Electrical Contact Resistances for TEG and TEC.

Unit 3: EMI environment: Sources of EMI- conducted and radiated EMI- Practical Experiences and Constraints – An Overview of EMI and EMC – Analytical examples – Celestial Electromagnetic Noise – Lightning discharge – ESD - EMP.

Unit 4: EMI/EMC issues and its mitigation: EMI standards, radiated emission, conducted emission, line impedance stabilization network (LISN) for emission and susceptibility tests, mitigation techniques using EMI filter, PCB layout and rcd snubber types of noise (CM – DM), EMI filter design for common mode and differential mode noise, transient and surge suppression devices – EMC accessories.

Text Books:

1. Kodali V.P., "Engineering EMC Principles, Measurements and Technologies", IEEE Press, 2001.
2. Thermal Design: Heat Sinks, Thermoelectrics, Heat Pipes, Compact Heat Exchangers, and Solar Cells by Ho Sung Lee, John Wiley & Sons Inc, 2010.
3. EMC in Power Electronics Tihanyi, Laszlo

Reference Books:

1. Halid Hrasnica, Abdelfatteh Haidine & Ralf Lehnert,'Broadband Powerline Communications Networks: Network Design, John Wiley & Sons Ltd, 2004.
2. Design and Analysis of Heat Sinks by Allan D. Kraus,John Wiley & Sons Inc, 1995.

3. Heat Transfer: Thermal Management of Electronics, by Younes Shabany, CRC Press, 2009.
4. Thermal Computations for Electronics: Conductive, Radiative, and Convective Air Cooling by Gordon Ellison, CRC Press 2010.
5. Kodali V.P., "Engineering EMC Principles, Measurements and Technologies", IEEE Press,1996.
6. Mark I Montrose., "EMC and the Printed Circuit Board Design, Theory and Layout Made Simple", IEEE Press, 1999

Course Outcome: At the end of this course, students will be able to:

1. Design proper size of heat sinks
2. Evaluate the thermoelectric effect and its application.
3. Examine the EMI/EMC issues and its mitigation.

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	3	2	1	3
CO 2	3	3	2	2
CO 3	3	3	2	2

3- High, 2- Medium, 1-Low

EE 6398	Project Phase -I M. Tech in Power Electronics and Drives Electrical Engineering Branch	L	T	P	C
		-	-	-	06

Course Outcomes: At the end of this project phase I, students will be able to:

1. Identify the complex engineering problem and find possible solutions.
2. Apply the technical, software, and hardware knowledge to carry out their project work.
3. Create technical report of the project work.
4. Communicate the findings technically in written and oral forms with engineering community at large.

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	3	3	3	3
CO 2	3	3	3	3
CO 3	3	3	3	3
CO 4	3	3	3	3

3- High, 2- Medium, 1-Low

EE 6399	Project Phase -II	L	T	P	C
	M. Tech in Power Electronics and Drives	-	-	-	08
	Electrical Engineering Branch				

Course Outcomes: At the end of this project phase I, students will be able to:

1. Identify the complex engineering problem and find possible solutions.
2. Apply the technical, software, and hardware knowledge to carry out their project work.
3. Create technical report of the project work.
4. Communicate the findings technically in written and oral forms with engineering community at large.

CO-PO Mapping (Articulation Matrix)

CO/PO	PO1	PO2	PO3	PO4
CO 1	3	3	3	3
CO 2	3	3	3	3
CO 3	3	3	3	3
CO 4	3	3	3	3

3- High, 2- Medium, 1-Low