PUDUCHERRY TECHNOLOGICAL UNIVERSITY
PUDUCHERRY–605014

(*A Technological University of Government of Puducherry*)

Curriculum and Syllabi

of

M.Tech in Electrical Drives and Control

(With effect from Academic year 2020-21)

(Approved in the Sixth Academic Council Meeting held on 20th March 2021)

CURRICULUM

The curriculum for M.Tech. (Electrical Drives & Control) offered by the department of Electrical and Electronics Engineering is designed to fulfill the Programme Educational Objectives (PEO) and Programme Outcomes (PO) listed below:

PROGRAMME EDUCATIONAL OBJECTIVES (PEO)

PEO1	To equip the engineering graduates with good technical knowledge and competency in the areas of Electrical Drives and Control to design, develop and analyze solid state drive systems with intelligent and robust controllers.
PEO2	Graduates will pursue lifelong learning for innovative engineering solutions through research and complex problem-solving skills.
PEO3	Function effectively as an individual or as a team member with good communication and interpersonal skills in professional environment.
PEO4	Keep abreast with the latest technology and toolset.
PEO5	Discharge their professional responsibilities with integrity and self- discipline and a good understanding of their roles in society.

PROGRAMME OUTCOMES (PO)

PO1	Acquire in-depth knowledge of novel types of electric drives and power converters as well as their associated control system.
PO2	Achieve the ability to investigate the critical problems in Electric drives and control and solve such problems by applying theoretical and practical considerations.
PO3	Acquire necessary skills to effectively model, analyze and solve the engineering problems in Electric Drives and Control field.
PO4	Ability to use advanced technical skills and modern scientific tools for professional practice.
PO5	Extend their knowledge by literature survey, generate innovative ideas and taking up research and development work.
PO6	Capability to work with a team of Engineers / Researchers to take up and solve new challenges of multidisciplinary nature in the field of electrical drives and control.
PO7	Communicate effectively through oral and written presentation of technical reports.
PO8	Ability to take up the research and development projects in the area of Electric drives encompassing financial challenges, time management and organizational skills.
PO9	Develop the attitude to sustain the lifelong learning process by the way of participating in various professional activities and utilize the skills and knowledge so acquired to solve the problems in the field of power electronics.
PO10	Best utilize the acquired knowledge to solve the real life problems associated with the common man of the society in the most ethical manner, so that the standard of life will be enhanced.
PO11	Attain the ability to understand and learn the novel ideas through the self-learning process and to utilize such knowledge in solving the problems in the area of power electronics.
PO12	Ability to design and implement appropriate robust controllers for power converters used in sustainable energy technologies and to explore novel technologies to solve power quality problems.

PROGRAMME SPECIFIC OUTCOMES (PSO)

PSO1	Develop technical knowledge, skill and competence in the field of power electronics, electric drives and control and deal with the rapid pace technology innovation, industrial automation and developments.
PSO2	Ability and Skill to apply power electronics technology and control techniques to modern electrical drives, power system operation and control with conventional and non-conventional energy systems, smart grid, electric vehicles and such multidisciplinary engineering fields.
PSO3	Ability to communicate effectively with excellent interpersonal skills and demonstrate the practice of professional ethics for societal benefits.

Distribution of Credits among the subjects grouped under various categories:

Courses are grouped under various categories and the credits to be earned in each category of courses are as follows:

Sl. No.	Category	Credits	Course Category Code (CCC)
1	Programme Core Course	24	PCC
2	Programme Specific Elective Courses	15	PSE
3	Open Elective Courses	03	OEC
4	Professional Activity Courses (Project Work, Seminar)	28	PAC
5	Mandatory Audit Courses	Non - Credit	MAC
	Total	**70**	

Semester Wise Courses and Credits

Semester - I

Course Code	Course	CCC	Periods			Credits
			L	T	P	
EE251	Analysis of Power Converters	PCC	3	0	0	3
EE252	Modern Control Theory	PCC	3	0	0	3
EE253	Solid State Controlled Electrical Drives	PCC	3	0	0	3
EEZNN	Programme Specific Elective - 1	PSE	3	0	0	3
EEZNN	Programme Specific Elective - 2	PSE	3	0	0	3
EE254	Solid State Systems Laboratory	PCC	0	0	4	2
EE255	Research Methodology and IPR	PCC	2	0	0	2
AD2NN	Audit Course - I	MAC	2	0	0	0
Total			**23**			**19**

Semester - II

Course Code	Course	CCC	Periods			Credits
			L	T	P	
EE256	Digital Control systems	PCC	3	0	0	3
EE257	Special Electrical Machines and Drives	PCC	3	0	0	3
EE258	Vector Controlled AC Drives	PCC	3	0	0	3
EEZNN	Programme Specific Elective - 3	PSE	3	0	0	3
EEZNN	Programme Specific Elective - 4	PSE	3	0	0	3
EE259	Electrical Drives Laboratory	PCC	0	0	4	2
EE260	Mini Project and Seminar	PAC	0	0	4	2
AD2NN	Audit Course – II	MAC	2	0	0	0
Total			**25**			**19**

Semester - III

Course Code	Course	CCC	Periods			Credits
			L	T	P	
EEZNN	Programme Specific Elective - 5	**PSE**	3	0	0	3
OE2NN	Open Elective	**OEC**	3	0	0	3
EE261	Dissertation – Phase I	**PAC**	0	0	20	10
Total			**26**			**16**

Semester - IV

Course Code	Course	CCC	Periods			Credits
			L	T	P	
EE262	Dissertation – Phase II	**PAC**	0	0	32	16
Total			**32**			**16**

Programme Specific Electives (PSE):

Semester - I	**PSE-1 & PSE-2**	**EEZ01**	Advanced Digital Signal Processing
		EEZ02	FPGA based System Design
		EEZ03	Neural Networks
		EEZ04	Optimal Control Systems
		EEZ05	Soft Computing Techniques
		EEZ06	Wind Energy Conversion Systems
Semester - II	**PSE-3 & PSE-4**	**EEZ07**	Embedded Systems
		EEZ08	Control for Power Electronic Systems
		EEZ09	Electric Vehicles and its Developments
		EEZ10	Modern Power Electronic Converters
		EEZ11	Power Electronics in Power Systems
		EEZ12	Power Quality
Semester - III	**PSE-5**	**EEZ13**	Distributed Generation and Microgrid
		EEZ14	Flexible AC Transmission System Controllers
		EEZ15	Variable Structure Systems and Sliding Mode Control

Open Elective Courses (OEC)

OE201	Business Analytics (IT)
OE202	Industrial Safety and Maintenance (ME)
OE203	Operations Research (ME)
OE204	Cost Management of Engineering Projects (CE)
OE205	Composite Materials (PH)
OE206	Waste to Energy (CE)

Audit Courses (MAC)

AD201	English for Academic Writing (HS)
AD202	Disaster Management (CE)
AD203	Value Education (HS)
AD204	Constitution of India (HS)
AD205	Pedagogy Studies (HS)
AD206	Stress Management by Yoga (HS)

Department: **Electrical and Electronics Engineering**		Programme: **M.Tech. (Electric Drives and Control)**							
Semester: **First**		Course Category Code: **PCC**				Semester Exam Type: **TY**			
Course Code	Course Name	Periods / Week			Credit	Maximum Marks			
		L	T	P		CA	SE	TM	
EE251	**ANALYSIS OF POWER CONVERTERS**	3	-	-	3	40	60	100	
Prerequisite	-								
Course Outcome	**CO1**	The students will be able to acquire and apply knowledge of mathematics in power converter analysis.							
	CO2	The students will be able to understand the electrical circuit concepts behind the different working modes of power converters.							
	CO3	The students will be able to model, analyze and understand power electronic circuits and thereby capable of forming simulation study for generic load and machine load.							
	CO4	The students will be able to do calculation of performance parameters of power converters under various operating modes.							
	CO5	The students will be able to construct improved converter topologies for specific applications.							

UNIT I	**AC-DC Converters**	**Periods :9**	
Single phase and three phase-controlled rectifier – operation and performance analysis of half and fully controlled converter with RL, RLE loads with and without freewheeling diodes - converter - inverter operation - effect of source impedance - performance parameters at input and output - Power factor improvement techniques-Dual converters.			**CO1**
UNIT II	**AC-AC Converters**	**Periods :9**	
Principle of operation of cycloconverters – Single-phase and Three-phase cycloconverters -output voltage- - pulse generation and control circuit. Introduction to bi-directional switches - Single phase and three phase ac voltage controller- output voltage control – phase angle range – performance analysis – gating requirements.			**CO2**
UNIT III	**DC-DC Converters**	**Periods :9**	
DC choppers - principle- control strategies - forced commutated principle - voltage and current commutated choppers - choice of commutation circuit element – class A, B, C, D and E choppers – chopper design – applications – design principles.			**CO3**
UNIT IV	**DC-AC Converters**	**Periods :9**	
Single Phase Inverters: Principle - half and full bridge inverters – Performance parameters – Voltage control - different PWM techniques – harmonic elimination methods. Three Phase Inverters: 180 degree and 120-degree conduction mode inverters with star and delta connected loads – voltage control of three phase inverters: single, multi pulse, sinusoidal, space vector modulation techniques – Current source inverters.			**CO4**
UNIT V	**High Power Applications**	**Periods:9**	
High power converters - higher pulse operation - series connected – parallel connected converters - Introduction to multilevel inverters - diode clamped, flying capacitor, cascade type multilevel inverters - comparison of multilevel inverters – application of multilevel inverters – Single phase and three phase impedance source inverters.			**CO5**
Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books :

1. Rashid M.H., “Power Electronics Circuits, Devices and Applications ", Prentice Hall India, fourth Edition,

New Delhi, 2014.
2. M.D.Singh and K.B.Khanchandani, “Power Electronics”, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2003.
3. P.S.Bimbhra, “Power Electronics”, Khanna Publishers, Eleventh Edition, 2003.
4. Bimal.K.Bose “Modern Power Electronics and AC Drives”, Pearson Education, Second Edition, 2003.
5. NedMohan, T.M.Undeland and W.P.Robbins, “Power Electronics: converters, Application and design” John Wiley and sons. Wiley Indiaedition, 2006.
6. T.krein, “Elements of Power Electronics” OxfordUniversityPress-1998.
7. P.C.Sen, “Modern Power Electronics”, Wheeler Publishing Co, First Edition, New Delhi,1998.
8. Bin Wu, Mehdi Narimani, "High-power Converters and AC Drives", Wiley,2ndEdition,2017
9. Cyril Lander, “Power Electronics”, McGraw Hill International Edition, 1993.
10. J.Arrillaga, Yonghe H. Liu, N.R. Watson, N.J. Murray, Self-Commutating Converters for High Power Applications”, John Wiley &Sons, 2009.

CO – PO Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1			3	1		2			2		1		3	3	1
CO2	1		3		1	2			2		1		3	3	1
CO3	3		3	1		2			2	2			3	3	1
CO4	3		3	1		2			2		1		3	3	1
CO5			3	1		2			2		1		3	3	1

Score: **3** – High; **2** – Medium; **1** – Low

Department: **Electrical and Electronics Engineering**			Programme: **M.Tech (Electric Drives and Control)**						
Semester: **First**			Course Category Code: **PCC**			Semester Exam Type: **TY**			
Course Code	Course Name		Periods / Week			Credit	Maximum Marks		
			L	T	P		CA	SE	TM
EE252	**MODERN CONTROL THEORY**		3	-	-	3	40	60	100
Prerequisite	Linear Control Systems								
Course Outcome	**CO1**	The students will be able to model the given system using state space approach. They will learn different forms of state space model and understand the conversion of one form into another.							
	CO2	The student will able to find the solution of state equation for the given external input. They will also learn to test the controllability and observability properties for the given state space system.							
	CO3	The students will be able to design controller for the state space system using pole placement technique. The students should be able to design observers for the given state space system.							
	CO4	The students will be able to analyze the stability of the given state space system using Lyapunov method.							
	CO5	The students will be able to formulate optimal controller problems and also able to design optimal control law for the given problem.							

UNIT I	**Introduction to State Space Approach**	**Periods :9**
Modeling of physical systems using state space approach – advantages of state space model over transfer function model. State diagram, state space and state trajectory – state space realization – controllable, observable, diagonal and Jordan canonical forms – Similarity transformation – Transformation into various canonical realizations - Eigen values and Eigen vectors - Derivation of transfer function from state model.		**CO1**
UNIT II	**State Space Analysis**	**Periods :9**
Solution of Linear Time Invariant (LTI) state equation – state transition matrix and its properties – computational techniques- Cayley Hamilton theorem–minimal polynomial concept–Sylvester's interpolation method- Controllability and Observability – Tests for controllability and observability.		**CO2**
UNIT III	**State Feedback Control Design**	**Periods :9**
Controller design by state feedback –Necessary and Sufficient condition for arbitrary pole placement-state regulator problem - Tracking (Servo) problem – State feedback with integral control. Observer Design – Full order/reduced order observer design – observer based state feedback control – separation principle.		**CO3**
UNIT IV	**Stability Analysis**	**Periods :9**
Stability concepts–BIBO Asymptotic stability-stability definitions in states pace domain–stability theorems on local and global stability – Lyapunov stability analysis – Krasovskii's Method-Variable Gradient method - Lyapunov stability analysis of Linear Time Invariant (LTI) systems.		**CO4**
UNIT V	**Optimal Control**	**Periods:9**
Linear quadratic optimal regulator (LQR) problem formulation – optimal regulator design by parameter adjustment (Lyapunov method) – optimal regulator design by Continuous - time Algebraic Riccatti Equation (CARE)-introduction to Kalman filter- optimal controller design using LQG framework.		**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books :

1. Katsuhiko Ogata, "Modern Control Engineering", Prentice Hall of India pvt. Ltd., NewDelhi, 2010.

2. Biswa Nath Datta, “Numerical Methods for Linear Control Systems”, Elsevier, 2005.
3. Gene.F.Franklin, J.David Powell and Abbas Emami-Naeini, “Feedback Control of Dynamic Systems”, Pearson Edu. Asia, 2014.

CO – PO Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	2	2	2				1	3	3	3	3	
CO2	3	3	3	2	2	2				1	3	3	3	3	
CO3	3	3	3	2	2	2				2	3	3	3	3	
CO4	3	3	3	2	2	2				1	3	3	3	3	
CO5	3	3	3	2	2	2				2	3	3	3	3	

Score: **3** – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="3">Department: Electrical and Electronics Engineering</td><td colspan="7">Programme: M.Tech (Electric Drives and Control)</td></tr>
<tr><td colspan="3">Semester: First</td><td colspan="4">Course Category Code: PCC</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2" colspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>EE253</td><td colspan="2">SOLID STATE CONTROLLED ELECTRICAL DRIVES</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="9">-</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="8">Understanding the industrial requirements and choosing the electrical motor drives and its ratings for the desired applications.</td></tr>
<tr><td>CO2</td><td colspan="8">Ability to design converter & chopper fed dc drives with/without closed loop controllers</td></tr>
<tr><td>CO3</td><td colspan="8">Ability to understand closed loop speed control of solid state converter/inverter fed induction motor drives from stator side.</td></tr>
<tr><td>CO4</td><td colspan="8">Ability to understand closed loop speed control of solid state system driven induction motor drives from rotor side.</td></tr>
<tr><td>CO5</td><td colspan="8">Able to design of open & closed speed control of solid state system driven Synchronous motor drives with various power controllers.</td></tr>
<tr><td>UNIT I</td><td colspan="6">Speed Control of DC Motors</td><td colspan="3">Periods :9</td></tr>
<tr><td colspan="9">Industrial motor drive requirements – typical load torque speed curves-energy savings-variable speed drives load dynamics and modeling - load type and duty ratio - motor choice - speed control principles - constant torque - constant power -multi quadrant operations.
Solid state controlled DC motor - converter fed – chopper fed – operating modes – configurations - speed control torque control - speed reversal - braking - regeneration - closed loop regulation - Inching - jogging - effect of saturation.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="6">Design of Controller and Converter for DC Drives</td><td colspan="3">Periods :9</td></tr>
<tr><td colspan="9">Closed loop operation - speed regulation - speed loop - current loop - tracing of waveforms - speed reversal - torque reversal - with/ without braking and regeneration - design of converters and choppers - firing scheme - simulation. Modeling of dc motors, converters, choppers - controller design, speed controller, current controller - performance analysis with and without current controller - simulation.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="6">Speed Control of Induction Motor - Stator Side</td><td colspan="3">Periods :9</td></tr>
<tr><td colspan="9">Comparison of different ac power controllers - principles of speed control - variable voltage – variable frequency operation - constant flux operation - constant power operation - speed control of VSI and CSI fed drives - design examples. Closed loop control schemes - dynamic and regenerative braking - speed reversal - tracing of critical waveforms - effect of non- sinusoidal supply.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="6">Speed Control of Induction Motor - Rotor Side</td><td colspan="3">Periods :9</td></tr>
<tr><td colspan="9">Torque slip characteristics-speed control through slip-rotor resistance control – chopper controlled resistance equivalent resistance - TRC strategy - characteristic relation between slip and chopper duty ratio - combined stator voltage control and rotor resistance control - design solutions - closed loop control scheme. Slip power recovery - torque slip characteristics - power factor considerations - sub and super synchronous operation - design solutions - closed loop control scheme.</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="6">Speed Control of Synchronous Motor Drives</td><td colspan="3">Periods:9</td></tr>
<tr><td colspan="9">Need for leading PF operation - open loop VSI fed drive - group drive applications. Self-control - margin angle control-torque angle control-power factor control-simple design examples. Closed loop speed control scheme with various power controllers - starting methods - brush less excitation systems.</td><td>CO5</td></tr>
</table>

Lecture Periods: 45	Tutorial Periods: -	Practical Periods: -	Total Periods: 45

Reference Books :

1. R.Krishnan, “Electric Motor Drives-Modeling, Analysis and Control”, Prentice-Hall of India Pvt. Ltd., New Delhi, 2003.
2. BimalK.Bose,“Modern Power Electronics and AC Drives”, Pearson Education (Singapore) Pvt. Ltd., New Delhi, 2003.
3. Bin Wu, “High - Power Converters and AC Drives”, Wiley - IEEE Press, March2017
4. Austin Hughes, Newnes, “Electric Motors and Drives: Fundamentals, Types and Applications”, Jan 2006.
5. G.K.Dubey, “Power semiconductor controlled devices”, Prentice Hall International New Jersey, 1989, ePub, August 2020.
6. G. K. Dubey, “Fundamentals of Electrical Drives”, CRC Press,2ndEdition,2002
7. Werner Leonhard, “Control of Electrical Drives”, 3rdEdition, Springer, Sept., 2001.
8. Jean Bonal and Guy Seguier, “Variable Speed Electric Drives”, Lavoisier c/o Springer-Verlag, May, 2000.
9. Buxbaum, A.Schierau, and K.Staughen, “A design of control systems for DC drives”, Springer-Verlag, 1990.
10. J.M.DMurphy, F.G.Turnbull, “Thyristor control of AC motors”, Pergam on Press, Oxford, 1988”, John Wiley & Sons, 2009.

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	2	1	1	1	1	1	2	2	2	1	3	3
CO2	3	3	3	2	1	1	1	3	1	2	2	2	1	3	3
CO3	3	3	3	2	1	1	1	3	1	2	2	2	1	3	3
CO4	3	3	3	2	1	1	1	3	1	2	2	2	1	3	3
CO5	3	3	3	2	1	1	1	3	1	2	2	2	1	3	3

Score: **3** – High; **2** – Medium; **1** – Low

Department: **Electrical and Electronics Engineering**			Programme: **M.Tech (Electric Drives and Control)**						
Semester: **First**			Course Category Code: **PCC**			Semester Exam Type: **LB**			
Course Code	Course Name		Periods / Week			Credit	Maximum Marks		
			L	T	P		CA	SE	TM
EE254	**SOLID STATE SYSTEMS LABORATORY**		-	-	4	2	40	60	100
Prerequisite	Power Electronics								
Course Outcome	**CO1**	The students will be able to explain the working, design and analyze the performance of high power AC- DC and DC-DC power converters.							
	CO2	The students will be able to comprehensively explain the working, develop and performance study the thyristor based FACTS devices.							
	CO3	The students will be able to understand the different Power Electronics Systems to vary the AC voltage. Also able to contemplate the working of different VSIs and also the static tap changing transformer.							

List of Experiments :

1. Firing Pulse Generation Schemes for Two Pulse and Six Pulse Converters. 2. Power Factor Improvement Methods. 3. Higher-Pulse Converters. 4. DC-DC Converters.	**CO1**
5. Thyristor Controlled Reactor. 6. Thyristor Switched Capacitor. 7. Thyristor Controlled Series Compensator. 8. Three/Six Phase Delta Connected Thyristor Controlled Reactor.	**CO2**
9. Static Tap Changing of Transformer. 10. Three Phase Voltage Source Inverter. 11. Single Phase Sinusoidal PWM Inverter. 12. Multi-Level Inverters.	**CO3**

Lecture Periods: -		**Practical Periods: 60**	**Total Periods: 60**

Reference Books :

1. Rashid M.H., "Power Electronics Circuits, Devices and Applications ", Prentice Hall India, fourth Edition, New Delhi, 2014.
2. Bin Wu, "High Power Converters and AC Drives" John Wiley & Sons, Inc., Hoboken, New Jercy.
3. Vijay K. Sood, HVDC and FACTS Controller: Application of Static Converters in power systems, IEEE Power Electronics and Power Systems series, Kluwer Academic publishers,Boston,2004.

CO – PO Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	2	3	1	1	2	2	1	1	1	2	3	2	1
CO2	3	3	2	3	1	1	2	2	1	1	1	2	3	2	1
CO3	3	3	2	3	1	1	2	2	1	1	1	2	3	2	1

Score: **3** – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Electrical and Electronics Engineering</td><td colspan="7">Programme: M.Tech (Electric Drives and Control)</td></tr>
<tr><td colspan="2">Semester: First</td><td colspan="4">Course Category Code: PCC</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>EE255</td><td>RESEARCH METHODOLOGY AND IPR</td><td>2</td><td>-</td><td>-</td><td>2</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8">-</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="7">Understand the objectives, types and significance of research.</td></tr>
<tr><td>CO2</td><td colspan="7">Describe the concept of research problem and necessity of review of literature.</td></tr>
<tr><td>CO3</td><td colspan="7">Analyze the different types of experimental research designs.</td></tr>
<tr><td>CO4</td><td colspan="7">Discuss the procedural steps of data collection, interpretation and report writing.</td></tr>
<tr><td>CO5</td><td colspan="7">Explain the acts and agreements related to intellectual property.</td></tr>
<tr><td>UNIT I</td><td colspan="5">Research Methodology</td><td colspan="3">Periods :6</td></tr>
<tr><td colspan="8">Introduction, Meaning of Research, Objectives of Research, Motivation in Research, Types of Research, Research Approaches, Significance of Research, Research Methods versus Methodology, Research and Scientific Method, Importance of Knowing How Research is Done, Research Process, Criteria of Good Research, and Problems Encountered by Researchers in India.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5">Defining the Research Problem and Review of Literature</td><td colspan="3">Periods :6</td></tr>
<tr><td colspan="8">Research Problem, Selecting the Problem, Necessity of Defining the Problem, Technique Involved in Defining a Problem, An Illustration. Place of the literature review in research, Bringing clarity and focus to your research problem, Enabling contextual findings, How to review the literature, searching the existing literature, reviewing the selected literature, Developing a conceptual framework, Writing about the literature reviewed.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5">Research Design</td><td colspan="3">Periods :6</td></tr>
<tr><td colspan="8">Meaning of Research Design, Need for Research Design, Features of a Good Design, Important Concepts Relating to Research Design, Different Research Designs, Basic Principles of Experimental Designs, Important Experimental Designs.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5">Data Collection, Interpretation and Report Writing</td><td colspan="3">Periods :6</td></tr>
<tr><td colspan="8">Experimental and Surveys, Collection of Primary Data, Collection of Secondary Data, Selection of Appropriate Method for Data Collection, Case Study Method. Meaning of Interpretation, Technique of Interpretation, Precaution in Interpretation, Significance of Report Writing, Different Steps in Writing Report, Layout of the Research Report, Types of Reports, Oral Presentation, Mechanics of Writing a Research Report, Precautions for Writing Research Reports.</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="5">Intellectual Property</td><td colspan="3">Periods:6</td></tr>
<tr><td colspan="8">The Concept, Intellectual Property System in India, Development of TRIPS Complied Regime in India, Patents Act, 1970, Trade Mark Act, 1999,The Designs Act, 2000, The Geographical Indications of Goods (Registration and Protection) Act1999, Copyright Act,1957,The Protection of Plant Varieties and Farmers' Rights Act, 2001,The Semi-Conductor Integrated Circuits Layout Design Act, 2000, Trade Secrets, Utility Models, IPR and Biodiversity, The Convention on Biological Diversity (CBD) 1992, Competing Rationales for Protection of IPRs, Leading International Instruments Concerning IPR, World Intellectual Property Organization (WIPO),WIPO and WTO, Paris Convention for the Protection of Industrial Property, National Treatment, Right of Priority, Common Rules, Patents, Marks, Industrial Designs, Trade Names, Indications of Source, Unfair Competition, Patent Cooperation Treaty (PCT), Advantages of PCT Filing, Berne Convention for the Protection of Literary and Artistic Works, Basic Principles, Duration of Protection, Trade Related Aspects of Intellectual Property Rights(TRIPS) Agreement, Covered under TRIPS Agreement, Features of the Agreement, Protection of Intellectual</td><td>CO5</td></tr>
</table>

Property under TRIPS, Copyright and Related Rights, Trademarks, Geographical indications, Industrial Designs, Patents, Patentable Subject Matter, Rights Conferred, Exceptions, Term of protection, Conditions on Patent Applicants, Process Patents, Other Use without Authorization of the Right Holder, Enforcement of Intellectual Property Rights, UNSECO.	

Lecture Periods: 30	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 30**

Reference Books :

1. Garg B.L., Karadia R, Agarwal F, and Agarwal, U.K., 2002. An introduction to Research Methodology, RBSA Publishers.
2. Kothari, C.R., 1990. Research Methodology: Methods and Techniques. New Age International.
3. Fink, A., 2009. Conducting Research Literature Reviews: From the Internet to Paper. Sage Publications
4. Leedy, P.D. and Ormrod, J.E., 2004. Practical Research: Planning and Design, Prentice Hall.
5. Satarkar, S.V., 2000. Intellectual property rights and Copy right. Ess Publications.

CO – PO Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1								1							
CO2		1			3	2									
CO3		1	3	2	2							1			
CO4		2	2				3								2
CO5						1				3					1

Score: **3** – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="3">Department: Electrical and Electronics Engineering</td><td colspan="7">Programme: M.Tech (Electric Drives and Control)</td></tr>
<tr><td colspan="3">Semester: Second</td><td colspan="3">Course Category Code: PCC</td><td colspan="4">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2" colspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>EE256</td><td colspan="2">DIGITAL CONTROL SYSTEMS</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="9">Linear Control Systems, Modern Control Systems, Matrix Algebra and Vector Analysis.</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="8">The students will be able to understand the basic building blocks of digital control systems, the components/devices involved and the analysis methodologies.</td></tr>
<tr><td>CO2</td><td colspan="8">The students will be able to express a digital control system in state space framework and compute the solution when subjected to an external input.</td></tr>
<tr><td>CO3</td><td colspan="8">The students will be able to comprehend important attributes like controllability, observability of discrete- time systems. They should be able to test a system for controllability, observability and stability using standard techniques.</td></tr>
<tr><td>CO4</td><td colspan="8">The students will be able to design digital controllers using root locus and frequency response techniques. The students should be able to design a PID controller for a discrete-time system using Ziegler-Nichols tuning rules.</td></tr>
<tr><td>CO5</td><td colspan="8">The students will be able to design state feedback controller using direct state feedback and observer based state feedback. The students should be able to design optimal controllers and estimate state variables for stochastic discrete-time systems.</td></tr>
<tr><td>Unit I</td><td colspan="5">Introduction</td><td colspan="4">Periods :9</td></tr>
<tr><td colspan="9">Introduction to discrete-time control system. Sampling and holding - sample and hold device - D/A and A/D conversion circuits. Reconstruction of original signal from sampled signals - sampling theorem. Z transform – properties – inverse Z transform. Pulse transfer function.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5">State Variable Technique</td><td colspan="4">Periods :9</td></tr>
<tr><td colspan="9">State equations of discrete time systems – solution of state equation – state transition matrix and its properties. State space realization and state diagram. Pulse transfer function from state equation-characteristic equation - Eigen values and Eigen vectors. Similarity transformation – transformation into various canonical forms.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5">Controllability, Observability & Stability of Discrete-Time Systems</td><td colspan="4">Periods :9</td></tr>
<tr><td colspan="9">Controllability and observability of Linear Time Invariant (LTI) discrete-time systems – tests for controllability and observability – relationship between controllability, observability and pulse transfer functions. Stability of LTI discrete time systems - Jury's stability test – Bilinear transformation method. Stability analysis of discrete-time systems - Lyapunov stability analysis.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5">Classical Controller Design Techniques</td><td colspan="4">Periods :9</td></tr>
<tr><td colspan="9">Correlation between root locations in Z-plane and time response – transient and steady state response analysis. Design of digital controller design based on root locus and frequency response method. PID controllers – proportional, integral and derivative modes – discretization of continuous PID controller – Ziegler-Nichols tuning rules.</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="5">Modern Controller Design Techniques</td><td colspan="4">Periods:9</td></tr>
<tr><td colspan="9">State feedback control - Design via arbitrary pole placement – observer based state feedback – separation principle. Introduction to optimal control – linear quadratic optimal controller design using Riccatti equation. Introduction to Kalman filter and LQG controller framework.</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="2">Practical Periods: -</td><td colspan="4">Total Periods: 45</td></tr>
<tr><td colspan="10">Reference Books :
1. K. Ogata, 'Discrete time control systems', Pearson Edu.,2003.</td></tr>
</table>

2. Franklin, Powell, workman, ‘Digital control of Dynamic systems’, Pearson Edu., 2002.
3. M. Gopal, ‘Digital Control and state variable methods’, Tata McGraw Hill, New Delhi, 2003.
4. Benjin.Kuo, ‘Digital Control systems’, 2nd Edition, OxfordUniversity,1992.
5. Biswa Nath Dutta, ‘Numerical Methods for Linear Control Systems’, Elsevier, 2004.

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	1	3										2		
CO2		2	3	1									1	2	
CO3	1	3	2										2		
CO4	1	2	3										2	3	
CO5	1		3	2									2	3	

Score: **3** – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Electrical and Electronics Engineering</td><td colspan="7">Programme: M.Tech (Electric Drives and Control)</td></tr>
<tr><td colspan="2">Semester: Second</td><td colspan="3">Course Category Code: PCC</td><td colspan="4">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>EE257</td><td>SPECIAL ELECTRICAL MACHINES AND DRIVES</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8">Solid state controlled electric drives</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="7">To understand the fractional HP machines and applications.</td></tr>
<tr><td>CO2</td><td colspan="7">To gain knowledge about stepper motor configurations, driver circuits and control.</td></tr>
<tr><td>CO3</td><td colspan="7">Able to understand switched reluctance motors and control techniques.</td></tr>
<tr><td>CO4</td><td colspan="7">To study the operation and control of permanent magnet brushless dc motor.</td></tr>
<tr><td>CO5</td><td colspan="7">To Gain the knowledge of working of permanent magnet synchronous motor and doubly fed induction generator.</td></tr>
<tr><td>Unit I</td><td colspan="5">Single Phase AC Special Machines</td><td colspan="3">Periods :9</td></tr>
<tr><td colspan="8">Principle and construction of split phase motors - Shaded Pole motor - Repulsion motor – Universal motor – Hysteresis motor – Reluctance motor - AC and DC Servo motor – Linear Induction Motor – Schrage Motor – Characteristics and Applications.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5">Stepper Motor</td><td colspan="3">Periods :9</td></tr>
<tr><td colspan="8">Principle of operation – Construction and important features - Types of motors– Modes of operation – control of Stepper motor - Hybrid stepper motor – Static and Dynamic Characteristics - effect of the inductance of the motor windings – Unipolar and Bipolar drivers – open loop and closed loop control - applications.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5">Switched Reluctance Motor</td><td colspan="3">Periods :9</td></tr>
<tr><td colspan="8">Principle of operation – Constructional details-Torque production – Torque speed characteristics –Speed control – Power controllers – Static observers for rotor position sensing – volt- ampere requirements – Applications. Control of SRM Drives : SRM Structure - Stator Excitation - sensorless operation-convertor topologies - SRM drive design factors.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5">Permanent Magnet Brush Less DC Motor</td><td colspan="3">Periods :9</td></tr>
<tr><td colspan="8">Commutation in DC motors– Difference between mechanical and electronic commutators– Principle of operation- Construction–drive circuits–Torque and EMF equation– Torque and Speed characteristics-applications.
Control of BLDC Motor Drives: Sensing and logic switching scheme, BLDM as Variable Speed Synchronous motor-methods of reducing Torque pulsations.</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="5">Permanent Magnet Synchronous Motor & DFIG</td><td colspan="3">Periods:9</td></tr>
<tr><td colspan="8">Principles of operation–Constructional features of Permanent Magnet Synchronous Motor– Phasor diagram–Torque expression – Vector control-Applications. Principle and Construction of Doubly Fed Induction Generator-Characteristics-Control-Application in wind farm-merits and demerits.</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="2">Practical Periods: -</td><td colspan="3">Total Periods: 45</td></tr>
</table>

Reference Books :

1. Janardanan E.G, Special Electrical Machines, PHI, 2014
2. Venkataratnam K, Special Electrical Machines, Universities Press, Hyderabad, 3rd Edition 2009.
3. A.Hughes, Electric Motors and Drives, Affiliated East-West Press Pvt., Ltd., 2007.
4. K. Dhayalini, Special Electrical Machines, Anuradha Publications 2007.
5. T.J.E. Miller, ‘Brushless magnet and Reluctance motor drives’, Claredon press, London, 1989.
6. R.Krishnan, ‘Switched Reluctance motor drives’, CRC press, 2001.

7. R.Krishnan, Electric Motor Drives Modeling, Analysis, and Control, Prentice Hall of India, 2001.
8. P.P. Acarnley, Stepping Motors, A Guide to Modern theory and practice, Peter Peregrines, London, 2002.

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	1	2	2	2	3	3	2	2	2	3	1	2	2	3
CO2	2	1	2	1	2	3	3	2	2	2	3	1	2	2	3
CO3	2	1	2	1	3	3	3	3	2	2	3	2	2	2	3
CO4	2	2	2	2	3	3	3	3	2	2	3	2	2	2	3
CO5	2	2	2	2	3	3	3	3	2	2	3	2	2	2	3

Score: **3** – High; **2** – Medium; **1** – Low

Department: **Electrical and Electronics Engineering**	Programme: **M.Tech (Electric Drives and Control)**
Semester: **Second**	Course Category Code: **PCC** / Semester Exam Type: **TY**

Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
EE258	**VECTOR CONTROLLED AC DRIVES**	3	-	-	3	40	60	100

Prerequisite	Solid state controlled electric drives	
Course Outcome	**CO1**	The students will be able to incorporate closed loop control techniques using d-q transformation for various power converter applications.
	CO2	The students will be able to carry out d-q model for electrical machines.
	CO3	The student will be able to synthesize direct and indirect vector controller for induction machine.
	CO4	The students will be able to model, analyze and select the various control schemes suitable for synchronous machines.
	CO5	The students acquire the direct torque control concept of induction motor.

Unit I	**Dynamic Modelling of Induction Motor**	**Periods :9**
Vector control concept – dq axes – linear transformations in machines – Park's transformations, Stanley transformations and Kron's transformation -Dynamic modeling of induction machines- Generalized model in arbitrary reference frame, stator reference frame model, rotor reference frame model and synchronously rotating reference frame model - dynamic equivalent circuits; Dynamic model state space equations. Electromagnetic torque and flux linkage equations.		**CO1**
UNIT II	**Direct Vector Control of Induction Motor**	**Periods :9**
Principles of vector control- Scalar versus vector control, DC motor analogy. Direct vector control-FOC with rotor flux orientation, Flux vector estimation-voltage model and current model, FOC with stator flux orientation - Direct vector control of line side PWM rectifier- Vector control of CSI fed drives - vector control of cycloconverter drive.		**CO2**
UNIT III	**Indirect Vector Control of Induction Motor**	**Periods :9**
Indirect vector control – Phasor diagram, Derivation of indirect vector control scheme – flux and slip speed estimation, General schematic of IDVC, An implementation of IDVC for servo drive with open loop flux control, Speed controller design for an indirect vector-controlled induction motor drive.		**CO3**
UNIT IV	**Control of Synchronous Motor Drives**	**Periods :9**
d-q axis (Park) model of synchronous machines; Vector control of Synchronous motors – Field weakening mode; Control strategies- constant torque angle control, Unity power factor control, Constant mutual flux control, Optimum torque per ampere control and flux weakening control; Implementation using CSI.		**CO4**
UNIT V	**Direct Torque Control**	**Periods:9**
Direct torque and Flux Control- Torque expression with stator and rotor fluxes, Control strategy, DTC of Induction motor using Direct self-control and space vector modulation.		**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books :

1. Bimal K.Bose, "Modern Power Electronics and AC Drives, Pearson Education (Singapore) Ltd., New Delhi, 2003.
2. R.Krishnan, "Electric Motor Drives- Modeling, Analysis, and Control", Prentice-Hall of Indian Private Limited, New Delhi, 2003.
3. I Boldea and S.A.Nasar, "Vector Control of AC Drives", CRC Press LLC, 1992.
4. D.W. Novotny and T.A.Lipo, "Vector control and dynamics of AC drives", Oxford Science Publications, 1996.

5. Paul C. Krause, Oleg Wasynczuk and Scott D.Subhoff, “Analysis of Electric Machinery and Drive Systems”, IEEE Press, WileyInterscience,2002.
6. Nguyen Phung Quang and Jorg-Andreas Dittrich, “Vector Control of Three- phase AC Machines”, Springer Verlag Berlin and Heidelberg GmbH & Co.KG,2008.

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	1	2	1		1		1	1		1		3	2	1
CO2	1	1	2	1		1		1	1		1		3	2	1
CO3	1	1	2	1		1		1	1		1		3	2	1
CO4	1	1	2	1		1		1	1		1		3	2	1
CO5	1	1	2	1		1		1	1		1		3	2	1

Score: **3** – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Electrical and Electronics Engineering</td><td colspan="8">Programme: M.Tech (Electric Drives and Control)</td></tr>
<tr><td colspan="2">Semester: Second</td><td colspan="4">Course Category Code: PCC</td><td colspan="4">Semester Exam Type: LB</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>EE259</td><td>ELECTRICAL DRIVES LABORATORY</td><td>-</td><td>-</td><td>4</td><td>2</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8">Solid state drives</td></tr>
<tr><td rowspan="3">Course Outcome</td><td>CO1</td><td colspan="7">The students will be able to formulate, design and analyze the performance of power converters for DC machines.</td></tr>
<tr><td>CO2</td><td colspan="7">The students will be able to formulate, design and analyze the performance of power converters for AC machines.</td></tr>
<tr><td>CO3</td><td colspan="7">The students will be able to develop the mathematical modelling of various drive systems and learn the design of closed loop controllers.</td></tr>
<tr><td colspan="9">List of Experiments :</td></tr>
<tr><td colspan="8">Simulation study of following drive systems
1. Analysis of single phase angle-controlled converter drives and case study on closed loop speed control.
2. Analysis of three phase angle-controlled converter drives and case study on closedloop speed control.
3. Analysis of DC chopper drives and case study on closed loop speed controlling Pulse Generation Schemes for Two Pulse and Six Pulse Converters
Demonstration Experiment:
4. Study of single-phase Half controlled converter fed DC motor.</td><td>CO1</td></tr>
<tr><td colspan="8">Simulation study of following drive systems
5. V/f control of PWM inverter based three phase Induction motor.
6. V/f control of three phase Induction motor using Cyclo-converters
7. Rotor resistance scheme in wound-rotor Induction motor.
8. Slip Power recovery scheme in Wound rotor Induction Machine.
Demonstration Experiment:
9. Study of three phase Inverter fed induction motor drives</td><td>CO2</td></tr>
<tr><td colspan="8">Simulation study of following drive systems
10. Transfer function modelling of DC motor, and design of speed and current loop feedback PID controllers using Ziegler-Nichols tuning.
11. Development of compensators for speed control of DC Motor by using Bode Plot Technique.
12. Modeling and speed control of Permanent Magnet Brushless DC motor.
13. Modeling and Stability analysis of three phase induction motor drive using conventional methods (Root Locus technique, Bode plot, Nyquist plot).
14. Direct vector control of Induction Motor drive.
15. Indirect vector control of Induction Motor drive.
16. Sensorless Field Oriented Control for Permanent Magnet Synchronous Motor drive</td><td>CO3</td></tr>
<tr><td colspan="2">Lecture Periods: -</td><td></td><td colspan="3">Practical Periods: 60</td><td colspan="3">Total Periods: 60</td></tr>
</table>

Reference Books :

1. Rashid M.H., "Power Electronics Circuits, Devices and Applications", Prentice Hall India, fourth Edition, New Delhi, 2014.
2. Bimal K.Bose, "Modern Power Electronics and AC Drives", Pearson Education (Singapore) Ltd., New Delhi, 2003.
3. R.Krishnan, "Electric Motor Drives- Modeling, Analysis, and Control", Prentice-Hall of Indian Private Limited, New Delhi, 2003.

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	1	1	1	1		2	1	1	1	2	3	3	1
CO2	3	3	1	1	1	1		2	1	1	1	2	3	3	1
CO3	3	3	3	1	1	1		2	1	1	1	2	3	3	1

Score: **3** – High; **2** – Medium; **1** – Low

Department: **Electrical and Electronics Engineering**		Programme: **M.Tech (Electric Drives and Control)**							
Semester: **Second**		Course Category Code: **PAC**				Semester Exam Type: **LB**			
Course Code	Course Name	Periods / Week			Credit	Maximum Marks			
		L	T	P		CA	SE	TM	
EE260	**Mini Project and Seminar**	-	-	4	2	100	-	100	
Prerequisite	-								
Course Outcome	**CO1**	Ability to carry out a portion of a research work							
	CO2	Ability to extend the project to find an application for society							
	CO3	Ability to work in a team and present the ideas and thoughts with a clarity							
Mini Project									
The objective of the seminar is to enable the students to carry out the individual mini-project and present a seminar on any chosen topic related to Electrical Drives & Control and Power Electronics Applications. The topic shall be chosen in consultation with the Faculty coordinators. Each student is expected to make a detailed review of the literature, formulate the problem, carry out the mini project and prepare a report on the work done. The students should present the results of the work in the seminar. A departmental committee shall evaluate the performance of the students.									**CO1, CO2, CO3**
Lecture Periods: -		**Tutorial Periods: -**			**Practical Periods: 60**			**Total Periods: 60**	

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	3	3	3	2	2	2	2	3	3	3
CO2	3	3	3	3	3	3	3	3	2	2	2	2	3	3	3
CO3	3	3	3	3	2	2	3	3	3	3	2	2	3	3	3

Score: **3** – High; **2** – Medium; **1** – Low

Department: **Electrical and Electronics Engineering**		Programme: **M.Tech (Electric Drives and Control)**						
Semester: **Third**		Course Category Code: **PAC**			Semester Exam Type: **PR**			
Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
EE261	**Dissertation – Phase I**	-	-	20	10	250	250	500
Prerequisite	-							
Course Outcome	**CO1**	Ability to carry out literature survey, understand state of art techniques.						
	CO2	Ability to transform knowledge into an experimental process.						
	CO3	Ability to identify and apply appropriate tools to solve a problem.						
An individual project needs to be performed by each student under a supervisor. The work maybe analytical, experimental, design or combination of both. The student can undertake the 'Dissertation Work' in the department concerned or in an industry/research laboratory approved by the concerned Head of the Department. Specific research problem needs to be identified through a detailed literature survey in the areas of Electrical Drives & Control and Power Electronics Applications. The results obtained along with the literature survey have to be submitted as a report. Necessary inferences have to be drawn from the studies carried out and the same should be presented before the committee members. If the project involves the intensive analytical procedure, the analysis has to be completed and suitable comparison to existing methodologies reported in literature should be done to validate the correctness as well as the effectiveness of the work. Rigorous review by the committee will be carried out in the process to ascertain whether the work qualifies as a suitable project at the postgraduate level. The student is encouraged to present their work at National/International conferences.								**CO1, CO2, CO3**
Lecture Periods: -		**Tutorial Periods: -**			**Practical Periods: 300**		**Total Periods: 300**	

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	3	3	3	2	2	2	2	3	3	3
CO2	3	3	3	3	3	3	3	3	2	2	2	2	3	3	3
CO3	3	3	3	3	2	2	3	3	3	3	2	2	3	3	3

Score: **3** – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Electrical and Electronics Engineering</td><td colspan="7">Programme: M.Tech (Electric Drives and Control)</td></tr>
<tr><td colspan="2">Semester: Fourth</td><td colspan="4">Course Category Code: PAC</td><td colspan="3">Semester Exam Type: PR</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>EE262</td><td>Dissertation – Phase II</td><td>-</td><td>-</td><td>32</td><td>16</td><td>250</td><td>250</td><td>500</td></tr>
<tr><td>Prerequisite</td><td colspan="8">-</td></tr>
<tr><td rowspan="3">Course Outcome</td><td>CO1</td><td colspan="7">Ability to extend, improve, analyze and apply new strategies & techniques.</td></tr>
<tr><td>CO2</td><td colspan="7">Ability to design & develop prototype models.</td></tr>
<tr><td>CO3</td><td colspan="7">Ability to extend the work to a research.</td></tr>
<tr><td colspan="8">The problem identified in Phase-I may be further investigated. An improved solution may be provided. Simulation studies and/or hardware development would be completed. The hardware results will be compared with the simulation results to validate the effectiveness of the technique/algorithm/methodology proposed. The student’s contribution will be critically reviewed by a faculty committee and novel contributions will be encouraged for publication in any refereed National/International journals. A separate dissertation report needs to be submitted.</td><td>CO1, CO2, CO3</td></tr>
<tr><td colspan="2">Lecture Periods: -</td><td colspan="2">Tutorial Periods: -</td><td colspan="3">Practical Periods: 480</td><td colspan="2">Total Periods: 480</td></tr>
</table>

CO – PO Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	3	3	3	2	2	2	2	3	3	3
CO2	3	3	3	3	3	3	3	3	2	2	2	2	3	3	3
CO3	3	3	3	3	2	2	3	3	3	3	2	2	3	3	3

Score: **3** – High; **2** – Medium; **1** – Low

PROGRAMME SPECIFIC ELECTIVES

Department: **Electrical and Electronics Engineering**		Programme: **M.Tech (Electric Drives and Control)**							
Semester: **First**		Course Category Code: **PSE**				Semester Exam Type: **TY**			
Course Code	Course Name	Periods / Week			Credit	Maximum Marks			
		L	T	P		CA	SE	TM	
EEZ01	**ADVANCED DIGITAL SIGNAL PROCESSING**	3	-	-	3	40	60	100	
Prerequisite	Signals and systems/Digital signal processing								

Course Outcome	**CO1**	The students will be able to analyze the discrete time signals and able to find Z and inverse Z transforms.
	CO2	The students will be able to design digital filters for the given specifications.
	CO3	The students will be able to design adaptive filters.
	CO4	The students will be able to alter the sampling rates by designing decimators and interpolators.
	CO5	The students will be able to choose the required digital signal processor for any given applications.

UNIT I	**Discrete Time Signals**	**Periods : 9**	
Introduction to Discrete time signals – discrete time systems - LTI system-stability-properties-sampling frequency domain- Representation of discrete time signals and systems - Discrete random signals - Z-transforms – Properties - Inverse Z transforms.			**CO1**
UNIT II	**Digital Filter Design**	**Periods : 9**	
Design of IIR filter- filter structures - Design from analog filter; Design of FIR filters – structures – windowing – Design examples.			**CO2**
UNIT III	**Adaptive Digital Filters**	**Periods : 9**	
Adaptive filters-Examples of Adaptive filtering-The minimum mean square error criterion-The Widrow and Hoff LMS Algorithm – properties of LMS algorithm. Recursive Least Square (RLS) Algorithm – fast RLS algorithms – properties of RLS algorithms- Applications of adaptive filters.			**CO3**
UNIT IV	**Sampling Rate Alteration and Wavelet Transforms**	**Periods : 9**	
Decimators and Interpolators – Sampling rate conversion by a rational factor – implementation of sampling rate conversion – polyphase filter structures – multistate implementation of sampling rate conversion - Arbitrating factor sampling rate converter-Applications of multi–rate signal processing – design of phase shifter – interfacing of digital system with different sampling rates- continuous and discrete wavelet transforms-properties-applications of wavelet transform-noise reduction.			**CO4**
UNIT V	**Digital Signal Processors**	**Periods : 9**	
Digital signal processors - Introduction DSP processor memory Architecture - Some example of DSP processors - Pipelining - overview of TMS 320 family DSP processor - First generations TMS 320c1x to sixth generation TMS 320c6x processor.			**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books :

1. Sanjit K.Mitra, Digital signal processing: A Computer Based Approach, Mc Graw hill education, 2013.
2. Alan Oppenheim.V and Ronals W.Schafer, Digital Signal processing, Pearson Education India, 2015.
3. Proakis J.G. and Manolakis D. G., Digital Signal Processing Principles, Algorithms and Application, PHI, 2007.

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	2	3	2	1	1						3	2	2	
CO2	1	2	3	2	1	2						2	2	2	
CO3	1	2	3	2	1	2						3	2	2	
CO4	1	2	3	2	1	2						3	2	2	
CO5	3	3	3	2	1	2						3	2	2	

Score: **3** – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Electrical and Electronics Engineering</td><td colspan="7">Programme: M.Tech (Electric Drives and Control)</td></tr>
<tr><td colspan="2">Semester: First</td><td colspan="4">Course Category Code: PSE</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>EEZ02</td><td>FPGA BASED SYSTEM DESIGN</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
</table>

<table>
<tr><td>Prerequisite</td><td colspan="2">-</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td>The students will have an understanding of Programmable logic devices like PLA, PLD, FPGA and steps in digital design.</td></tr>
<tr><td>CO2</td><td>The student will develop the skill in the fundamental concepts of VHDL Programming.</td></tr>
<tr><td>CO3</td><td>The student will develop the skill in the advanced concepts of VHDL Programming.</td></tr>
<tr><td>CO4</td><td>The students will be able to design simple and complex combinational circuits using VHDL.</td></tr>
<tr><td>CO5</td><td>The students will be able to design simple and complex sequential circuits using VHDL.</td></tr>
</table>

<table>
<tr><td>UNIT I</td><td colspan="2">Introduction to Programmable Digital Hardware</td><td colspan="2">Periods :9</td></tr>
<tr><td colspan="4">Digital Hardware-The Design process. Programmable Logic Devices-Types-PLA, PAL, CPLD, FPGA - architectures. Custom chips, standard cells and Gate arrays. Implementation of circuits on programmable.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="2">Introduction to VHDL</td><td colspan="2">Periods :9</td></tr>
<tr><td colspan="4">Attributes-Value Kind, Function kind, Type kind. Aliases and Generate statements. Configurations, Generics and operator overloading. Subprograms – Functions and procedures. Packages - Package declaration and Package Body. RTL Synthesis. Simple Processor Design Combinational Circuit Design.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="2">Hardware-Applications</td><td colspan="2">Periods :9</td></tr>
<tr><td colspan="4">Multiplexers, Decoders ,Encoders, Code Converters- Binary to gray code, Binary to BCD converters, Binary to 7 segment, Adders, subtractors, Arithmetic Comparison Circuits VHDL for Combinational, Circuits Flip Flops Registers , Counters –up /down types .Memories-RAM, ROM types.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="2">Competitive & Self Organizing Networks</td><td colspan="2">Periods :9</td></tr>
<tr><td colspan="4">Advanced Topics in VHDL. Finite state machines using CAD tools-Moore and Mealy Machines-comparison. FSMs in VHDL-Design examples. Vending machine problem.</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="2">Sequential Circuit Design</td><td colspan="2">Periods :9</td></tr>
<tr><td colspan="4">Asynchronous Sequential Circuits synchronous - advantages and disadvantages - analysis, concept of stable and unstable, states, hazards and design example Vending machine controller.</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td>Tutorial Periods: -</td><td>Practical Periods: -</td><td>Total Periods: 45</td></tr>
</table>

Reference Books :

1. Stephen Brown, Zvonko Vranesic, Fundamentals of Digital Logic Design with VHDL, Tata Mc Graw Hill, Second Edition, 2007.
2. Douglas L. Perry, VHDL Programming by Example, Tata McGraw Hill Fourth Edition, 2012.
3. Charles H. Roth, Jr, Digital Systems Design Using VHDL, Thomson Learning, 2007.
4. Ben Cohen, VHDL Coding Styles and Methodologies, Springer, 2nd Edition, 2005.
5. Stainley Mazor, Patricia Langstraat, A Guide to VHDL, Springer, 2nd Edition, 2007.

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	2	2	2				1	3	3	3	3	
CO2	3	3	3	2	2	2				1	3	3	3	3	
CO3	3	3	3	2	2	2				2	3	3	3	3	
CO4	3	3	3	3	3	3				1	3	3	3	3	
CO5	3	3	3	3	3	3				2	3	3	3	3	

Score: **3** – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Electrical and Electronics Engineering</td><td colspan="7">Programme: M.Tech (Electric Drives and Control)</td></tr>
<tr><td colspan="2">Semester: First</td><td colspan="4">Course Category Code: PSE</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>EEZ03</td><td>NEURAL NETWORKS</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8">-</td></tr>
</table>

<table>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td>Knowledge of concepts and basic building blocks of artificial Neural Networks.</td></tr>
<tr><td>CO2</td><td>Apply supervised learning algorithms for different neural architectures.</td></tr>
<tr><td>CO3</td><td>Implement Associative learning techniques to electrical engineering problems.</td></tr>
<tr><td>CO4</td><td>Design neural network based systems using competitive and supervised learning.</td></tr>
<tr><td>CO5</td><td>Design neural network based intelligent models/control techniques for electrical Drives and control.</td></tr>
</table>

<table>
<tr><td>UNIT I</td><td>Introduction</td><td>Periods :9</td></tr>
<tr><td colspan="2">Introduction – Biological neural network – Artificial Neural network – comparison, motivation and Development. Neuron model – single / multiple inputs, transfer functions. Network architecture – single /multiple layers – Recurrent networks Perceptron network – architecture, learning rule, linear severability limitation.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td>Supervised Learning</td><td>Periods :9</td></tr>
<tr><td colspan="2">Learning mechanism – supervised learning – multiplayer perceptron for pattern classification and function approximation. The back propagation algorithm – numerical examples. Drawbacks in Back propagation – Momentum method, variable learning rate, Levenburg Marguardt Algorithm. Other supervised learning methods – supervised Hebb’s rule, Widrow Hoff learning rule – Adaline network.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td>Associative Networks</td><td>Periods :9</td></tr>
<tr><td colspan="2">Associative learning–unsupervised Hebb’srule–In star learning rule–Kohonen rule, Out-star rule–Pattern association – Hetero associative, Auto associative and Bi-directional associative memory – Discrete Hopfield network – Architecture, algorithm.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td>Competitive & Self Organizing Networks</td><td>Periods :9</td></tr>
<tr><td colspan="2">Competitive networks – Fixed weight competitive network – Kohonen Self-organizing maps – architecture, algorithm – Learning vector quantization – architecture, algorithm. Adaptive resonance theory – ART1; architecture, algorithm.</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td>Applications To Electrical Drives and Control</td><td>Periods :9</td></tr>
<tr><td colspan="2">Modelling – Space vector modulator, Estimation- Motor speed, flux, torque. Filtering using Neural Networks. Advances in neural computing techniques. Choice of Neural architectures and training algorithms for the various applications.</td><td>CO5</td></tr>
</table>

Lecture Periods: 45	Tutorial Periods: -	Practical Periods: -	Total Periods: 45

Reference Books :

1. Martin T.Hagan, Howard B.Demuth and Mark Beale, Neural Network Design– 2nd Edition, Thomson learning 2002.
2. Laurene Faseff, Fundamentals of Neural Networks-architecture, algorithm and application, Pearson Education 2004.
3. Kevin Gurney, Introduction to Neural Networks-Taylor and Francis, 2004.
4. James A. Freemen and David M. Skapura, Neural Networks-algorithms, applications and programming techniques, Addison Wesley Publishing House 1992.
5. Bimal K.Bose, Modern Power Electronics and AC Drives, Pearson Education (Singapore) Ltd., New Delhi, 2003.

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	2	3	2	2	3	1	1	2	2	3	2	1	2	2
CO2	1	2	3	3	3	3	1	1	2	2	3	3	1	2	2
CO3	1	2	3	3	3	3	1	1	2	2	3	3	1	2	2
CO4	1	2	3	3	3	3	1	1	2	2	3	3	1	2	2
CO5	3	2	3	3	3	3	2	1	2	2	3	3	2	2	2

Score: **3** – High; **2** – Medium; **1** – Low

Department: **Electrical and Electronics Engineering**		Programme: **M.Tech (Electric Drives and Control)**						
Semester: **First**		Course Category Code: **PSE**			Semester Exam Type: **TY**			
Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
EEZ04	**OPTIMAL CONTROL SYSTEMS**	3	-	-	3	40	60	100

Prerequisite	Linear Control Systems, Modern Control Systems, Matrix Algebra and Vector Analysis.

Course Outcome	**CO1**	The students will be able to understand the problem formulation techniques in the optimal control problems for dynamical systems modeled in state space approach.
	CO2	The students will be able to solve optimal control problems using dynamic programming method and assess the computational complexities involved in solving optimal control problems.
	CO3	The students will be able to optimize cost functions that involve single and multi-objective optimization problems with constraints.
	CO4	The students will be able to solve optimal control problems using the variational approach involving techniques like Pontryagin's minimum principle and linear quadratic problems.
	CO5	The students will be able to synthesize controllers for a dynamic system using numerical techniques.

UNIT I	**Performance Measure**	**Periods** : **9**	
Problem formulation - state variable representation of systems –performance measures for optimal control problems - selecting a performance measure.			**CO1**
UNIT II	**Dynamic Programming**	**Periods** : **9**	
Optimal control law – principle of optimality – Application of Principle of optimality to decision making – Recurrence relation of Dynamic Programming – Imbedding Principle – computational procedure to solve optimal control problems – Discrete Linear regulator Problems – Hamilton – Jacobi Belman Equation – Continuous linear regulator problems.			**CO2**
UNIT III	**Calculus of Variations**	**Periods** : **9**	
Fundamental concepts–Functional of a single function–functionals involving several independent functions – piece wise smooth extremals – constrained extrema.			**CO3**
UNIT IV	**Variational Approach to Optimal Control Problem**	**Periods** : **9**	
Necessary condition for optimal control – Linear regulator problems – Pontryagin's Minimum Principle and state inequality constraints – Minimum time Problems –Minimum Control – Effort problems – Singular intervals in optimal control Problem.			**CO4**
UNIT V	**Numerical Methods of Optimal Control**	**Periods** : **9**	
Simplex Method – golden section Method – Hill climbing – Gradient – Penalty functions methods.			**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books :

1. Donald. E. Kirk, Optimal Control Theory, an Introduction, Prentice Hall, Inc., Englewood Cliffs, New Jersey,
2. Brain D. O. Anderson and J. B. Moore, Optimal control, Prentice Hall, 1990.
3. Andrew P. Sage, Optimum Systems Control, Prentice Hall N.H.1968
4. Michael Athans and Peter L Falb, Optimal control, Dover publications, 2006.
5. Rao S.S., Optimization Theory and Application, Wiley Eastern, New Delhi, 1992.

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1			3	2	1								1	2	
CO2		3	1	2									3	2	
CO3			3	1	2								2	3	
CO4		3		2	1								1	2	
CO5			1	2	3								2	3	

Score: **3** – High; **2** – Medium; **1** – Low

Department: **Electrical and Electronics Engineering**	Programme: **M.Tech (Electric Drives and Control)**		
Semester: **First**	Course Category Code: **PSE**	Semester Exam Type: **TY**	

Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
EEZ05	**SOFT COMPUTING TECHNIQUES**	3	-	-	3	40	60	100

Prerequisite	-	
Course Outcome	**CO1**	Apply neural networks to pattern classification and regression problems and its applications and advances.
	CO2	Apply fuzzy logic and reasoning to handle uncertainty and solve engineering Problems.
	CO3	Apply genetic algorithms to combinatorial optimization problems and its applications and advances.
	CO4	Able to design using unified and exact mathematical basis and implement the various soft computing algorithms for solving the problems in Electrical Drives and Control.
	CO5	Able to design intelligent systems in many application areas and compare solutions by various soft computing approaches for a given problem.

UNIT I	**Neural Networks**	**Periods** : **9**
Learning rules and various activation functions-Single layer Perceptron's-Back Propagation networks - Architecture of Back propagation (BP) Networks – Back propagation Learning – Variation of Standard Back propagation Neural Network-Introduction to Associative Memory- Adaptive Resonance theory and Self Organizing Map.		**CO1**
UNIT II	**Fuzzy Systems**	**Periods** : **9**
Fuzzy Set theory - Fuzzy versus Crisp set - Fuzzy Relation – Fuzzification methods - Min-Max Composition - Defuzzification Methods - Fuzzy Logic - Fuzzy Rule based systems - Predicate logic - Fuzzy Decision Making - Fuzzy Control Systems - Fuzzy Classification.		**CO2**
UNIT III	**Genetic Algorithm**	**Periods** : **9**
Working Principle - Various encoding methods - Fitness function - GA Operators – Reproduction, Crossover, Mutation, Convergence of GA - Bit wise operation in GA - Multi-level Optimization.		**CO3**
UNIT IV	**Hybrid Systems**	**Periods** : **9**
Sequential Hybrid Systems - Auxiliary Hybrid Systems - Embedded Hybrid Systems - Neuro-Fuzzy Hybrid Systems - Neuro-Genetic Hybrid Systems - Fuzzy-Genetic Hybrid Systems.		**CO4**
UNIT V	**Ga and Fuzzy Based Back-Propagation Networks**	**Periods** : **9**
GA based Weight Determination - K-factor determination in Columns - Application of GA BP Networks - LR type Fuzzy numbers-Fuzzy Neuron-Fuzzy BP Architecture-Learning in Fuzzy BP-Application of Fuzzy BP Networks – Various applications for Modelling – Space vector modulator, Estimation- Motor speed, flux, torque. Filtering using GA and Fuzzy BP Networks.		**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books :

1. Kumar S., "Neural Networks - A Classroom Approach", Tata McGraw Hill, 2 nd Edison, 2009.
2. Timothy Ross, "Fuzzy Logic with Engineering applications", Willey, 4 th Edison, 2010.
3. Melanie Mitchell, "An Introduction to Genetic Algorithms", MIT Press, 2021.
4. S. Rajsekaran & G.A. Vijayalakshmi Pai, "Neural Networks, Fuzzy Logic and Genetic Algorithm: Synthesis and Applications" Prentice Hall of India, 2020.
5. J.-S.R.Jang, C.-T. Sun, E.Mizutani, "Neuro-Fuzzy and Soft Computing", Prentice Hall of India, 2009.

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1				3			2		3				3	3	3
CO2							2		3				3	3	3
CO3							2		3				3	3	3
CO4		2	2	3	3	3		3		3	3	2	3	3	3
CO5	2				3	3		3		3	3	2	3	3	3

Score: **3** – High; **2** – Medium; **1** – Low

Department: **Electrical and Electronics Engineering**		Programme: **M.Tech (Electric Drives and Control)**						
Semester: **First**		Course Category Code: **PSE**				Semester Exam Type: **TY**		
Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
EEZ06	**WIND ENERGY CONVERSION SYSTEMS**	3	-	-	3	40	60	100
Prerequisite	-							

Course Outcome	**CO1**	Acquire knowledge on the fundamentals of wind energy technology and its recent developments.
	CO2	Understand the different wind power extraction technologies.
	CO3	Ability to develop efficient wind energy systems and control methods.
	CO4	Know the grid integration requirements and techniques.
	CO5	Ability to design community based power generation with necessary storage.

UNIT I	**Introduction**	**Periods** : **9**
Historical developments, state of art of wind energy technology, turbine rating, Indian scenario and worldwide developments, present status and future trends. The nature and geographical variation in the wind resources – long term wind speed variation-annual and seasonal variations – diurnal variations, Turbulence, Gust wind Speeds –Extreme wind speeds – effect of height- wind rose – Power available in the wind.		**CO1**
UNIT II	**Wind Turbine Technology**	**Periods** : **9**
Wind turbine Aerodynamics- Aero foil lift, drag, stall; actuator disc concept- momentum theory and Betz coefficient –Types of Wind Turbines - pitch mechanism - rotor selection -various types of rotors of HAWT – Tip speed ratio – Solidity - effects of number of blades -Drive torque and rotor power—Wind turbine model – Wind speed and Direction measurements.		**CO2**
UNIT III	**Wind Energy System Configurations and Control**	**Periods** : **9**
Fixed speed Wind Energy Systems – Variable Speed systems - Types of generators - induction generator - equivalent circuit - efficiency - single phase operation of 3-phase induction generators - permanent magnet generator -synchronous generator – DFIG-– Direct Driven wind generators- –power regulation –active and passive stall control, yaw control, pitch control, MPPT tracking systems—modeling of Wind turbines for Power system studies.		**CO3**
UNIT IV	**Grid Integration of Wind Energy Systems**	**Periods** : **9**
Grid integration issues - Variability of wind power, Power quality issues – Islanding - Grid code requirements – steady state operational requirements, Low voltage ride through requirements – Power electronic converters for grid interface – Grid synchronization using PLL – Fault analysis-Protection - Small scale wind systems.		**CO4**
UNIT V	**Stand-Alone Wind Energy Systems**	**Periods** : **9**
Self-excitation process- effect of excitation capacitance -Equivalent circuit--voltage and frequency control techniques – Energy Storage – Batteries - Charge controllers - Direct Driven Generators - Wind/PV Hybrid System.		**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books

1. Gary L. Johnson, Prentice hall Inc., Englewood Cliffs, Wind Energy System, New Jersey, 1985.
2. Muyeen S M, Springer, Wind Energy Conversion Systems -Technology and Trends, 2012.
3. Qiuwei Wu, Yuanzhang Sun, Wiley – IEEE, Modeling and Modern Control of Wind Power, 2017.
4. L. Lfreris, Wind energy conversion system, Prentice hall (U.K) Ltd., 1990.

5. Remus Teodorescu, Marco Liserre, Pedro Rodriguez, Grid Converters for Photovoltaic and Wind Power Systems, Wiley - IEEEBook30.
6. N.Bhadra, D.Kastha and S. Banerjee, Wind electrical systems, Oxford University Press, 2005.
7. S.Ahmed, Wind Energy: Theory and Practice, PHI, 2010.
8. Tony Burton, David Sharpe, Nick Jenkins and Ervin Bossanyi, Hand Book of Wind Energy, John Wiley and sons, 2001.
9. Manfred Stiebler, Wind Energy Systems for Electrical Power Generation, Springer, 2008.
10. John D Sorensen and Jens N Sorensen, Wind Energy Systems, Wood head Publishing Ltd, 2011.

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1				1	2		3	2						1	3
CO2			2	1	2		3	2					1	1	3
CO3	2		3	2	2	1	3	2		2	2	3	2	2	3
CO4	2	2	3	3	2	2	3	2	3	2	3	3	3	2	3
CO5	1		3	3	2	2	3	2	3	2	3	3	3	2	3

Score: **3** – High; **2** – Medium; **1** – Low

Department: **Electrical and Electronics Engineering**	Programme: **M.Tech (Electric Drives and Control)**	
Semester: **Second**	Course Category Code: **PSE**	Semester Exam Type: **TY**

Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
EEZ07	**EMBEDDED SYSTEMS**	3	-	-	3	40	60	100
Prerequisite	Microprocessors and Microcontrollers							

Course Outcome	**CO1**	The students will have an understanding of the fundamental building blocks of embedded system.
	CO2	The student will acquire knowledge embedded system architecture.
	CO3	The student will be able to design embedded system using memory, timers and interrupt for different applications.
	CO4	Capability to design subsystems and interrupt routines using RTOs.
	CO5	Have acquired knowledge to interface data converters, test debug and build embedded systems.

UNIT I	**Introduction to Embedded Systems**	**Periods** : **9**
Introduction to embedded system -Definition and Classification – Overview of Processors and hardware units in an embedded system – Software embedded in to the system – Exemplary Embedded Systems – Embedded Systems on a Chip (SOC).		**CO1**
UNIT II	**Embedded System Architecture**	**Periods** : **9**
Microcontroller Architecture-Motorola 68HC11-PIC-Memory System Architecture-Caches-Virtual Memory - Memory Management Unit and Address Translation - I/0 Sub-system - Busy-wait I/0 - DMA - Interrupt driven I/0 -Co- processors and Hardware Accelerators - Processor Performance -Enhancement - Pipelining - Super-scalar Execution.		**CO2**
UNIT III	**Embedded Computing Platform**	**Periods** : **9**
CPU Bus – Bus Protocols – Bus Organization-Memory Devices and their Characteristics-RAM, ROM, UVROM, EEPROM, Flash Memory - DRAM - I/O Devices - Timers and Counters -Watchdog Timers - Interrupt Controllers – DMA Controllers.		**CO3**
UNIT IV	**Real Time Operating Systems**	**Periods** : **9**
Definitions of process, tasks and threads – I/O Subsystems – Interrupt Routines Handling in RTOS - RTOS Task scheduling models - Handling of task scheduling and latency and deadlines as performance metrics – Co-operative Round Robin Scheduling – Case Studies of Programming with RTOS.		**CO4**
UNIT V	**Validation and Testing of Embedded Systems**	**Periods** : **9**
A/D and D/A Converters - Displays - Keyboards - Infrared devices – Component Interfacing - Memory Interfacing - I/O Device Interfacing - Interfacing Protocols -Implementation - Development Environment - Debugging Techniques -Manufacturing and Testing.		**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books :

1. Rajkamal, “Embedded Systems Architecture, Programming and Design”, Tata McGraw-Hill, Third edition 2013.
2. Steve Heath, “Embedded Systems Design”, Second Edition, Elsevier India Pvt. Ltd., 2007.
3. Shibu K V, “Introduction to Embedded systems”, Tata McGraw Hill Firstprint-2009.
4. David E. Simon, “An Embedded Software Primer”, Pearson Education Asia, 2006.
5. Frank Vahid and Tony Givargis, “Embedded Systems Design – A unified Hardware /Software Introduction”, John Wiley, 2002.
6. Wayne Wolf, “Computers as Components; Principles of Embedded Computing System Design”, Morgan Kaufman Publishers, 2001.

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	2	2	2	1		2	1	3	3	3	3	
CO2	3	3	3	2	2	3	1		2	1	3	3	3	3	
CO3	3	3	3	2	2	3	1		2	2	3	3	3	3	
CO4	3	3	3	3	3	3	1		2	1	3	3	3	3	
CO5	3	3	3	3	3	3	1		2	2	3	3	3	3	

Score: **3** – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Electrical and Electronics Engineering</td><td colspan="9">Programme: M.Tech (Electric Drives and Control)</td></tr>
<tr><td colspan="2">Semester: Second</td><td colspan="4">Course Category Code: PSE</td><td colspan="5">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>EEZ08</td><td>CONTROL FOR POWER ELECTRONIC SYSTEMS</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8">Linear Control, Modern Control Systems, Power Converters and Electrical Machines.</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="7">The students will be able to understand the techniques involved in the design of controllers for dynamical systems with transfer function and state space modeling</td></tr>
<tr><td>CO2</td><td colspan="7">The students will be able to mathematical model different types of DC-DC power converters and design controllers for the converters.</td></tr>
<tr><td>CO3</td><td colspan="7">The students will be able to design controllers for single phase and three phase rectifier circuits and assess the closed-loop dynamic performance under time-varying perturbations in source and load.</td></tr>
<tr><td>CO4</td><td colspan="7">The students will be able to choose appropriate DC-DC converters for renewable energy applications and control the environment dependent fluctuating power generation under source and load variations.</td></tr>
<tr><td>CO5</td><td colspan="7">The students will be able to model BLDC and SRM motor and design controllers for sensor less speed control applications.</td></tr>
<tr><td>UNIT I</td><td colspan="5">Classical and Modern Controller Design Techniques</td><td colspan="3">Periods :9</td></tr>
<tr><td colspan="7">Review of Control System Concepts–Controller Design Techniques: Classical Techniques: Design of Lead and Lag Compensators – PID control – Tuning rules for PID controllers. Modern Techniques: Controllability and Observability concepts - Design of state feedback controller – Direct state feedback and observer based state feedback controller.</td><td colspan="2">CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5">Control of DC-DC Power Converters</td><td colspan="3">Periods :9</td></tr>
<tr><td colspan="7">State-space modeling of DC-DC power converters–Buck, Boost, Buck-Boost, Cuk, Sepic and Zeta converters. Analysis of open – loop system stability. Design of state feedback control for power converters–introduction to sliding mode controller design for power converters.</td><td colspan="2">CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5">Control of Rectifier Circuits</td><td colspan="3">Periods :9</td></tr>
<tr><td colspan="7">State-space modeling of single phase and three phase rectifiers. Design of direct state feedback and observer based state feedback controllers for rectifier circuits with nonlinear loads – performance analysis for load/source variations. Closed-loop analysis of continuous and discontinuous mode operation of rectifier circuits.</td><td colspan="2">CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5">Control of DC-DC Power Converters For RES Applications</td><td colspan="3">Periods :9</td></tr>
<tr><td colspan="7">Mathematical modeling of multi-input DC-DC converters for renewable energy applications like wind and solar systems. Design of state feedback controllers for multi-input DC-DC power converters–performance analysis for variations in source and load.</td><td colspan="2">CO4</td></tr>
<tr><td>UNIT V</td><td colspan="5">Control of BLDC Motor and SRM Motor</td><td colspan="3">Periods :9</td></tr>
<tr><td colspan="7">State-space model of brushless DC motor – design of state feedback controller for the speed control of BLDC motor with measurable states and estimated state variables (sensor-less speed control). Sliding mode control technique for BLDC motor. Modelling and control of switched reluctance (SRM) motor.</td><td colspan="2">CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="2">Practical Periods: -</td><td colspan="3">Total Periods: 45</td></tr>
</table>

Reference Books :

1. Sira -Ramirez, R. Silva Ortigoza, ‘Control Design Techniques in Power Electronics Devices’, Springer,2006
2. Siew-Chong Tan,Yuk-Ming Lai,ChiKong Tse,‘Sliding mode control of switching Power Converters’, CRC Press, 2011
3. Bimal Bose, ‘Power Electronics and Motor Drives’, Elsevier, 2006
4. Ion Boldea and S.A Nasar, ‘Electric Drives’, CRC Press, 2005.
5. Ned Mohan, Undeland and Robbin, ‘Power Electronics: converters, Application and design’, John Wiley and Sons. Inc, New York, 2006.
6. Rashid M. H., ‘Power Electronics-Circuits, Devices and Applications’, Prentice Hall India, New Delhi, 2009.
7. Ogata, K., ‘Modern Control Engineering’, Prentice Hall of India, 2010.
8. Hassan K. Khalil, ‘Nonlinear Systems’, Pearson Educational International Inc. Upper Saddle River, 3rd Edition.

CO – PO Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	1										3	1	
CO2		2	3	1									2	3	
CO3	2	3	1										1	3	
CO4				1								3	2	3	
CO5			2		1								3	2	

Score: **3** – High; **2** – Medium; **1** – Low

Department: **Electrical and Electronics Engineering**		Programme: **M.Tech (Electric Drives and Control)**						
Semester: **Second**		Course Category Code: **PSE**				Semester Exam Type: **TY**		
Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
EEZ09	**ELECTRIC VEHICLES AND ITS DEVELOPMENTS**	3	0	0	4	40	60	100
Prerequisite	Power Conversion Techniques, Electrical Machines							

Course Outcome	**CO1**	The students will be able to understand the basic concepts of electric vehicles.
	CO2	The students will be able to analyze the various energy storage methodologies.
	CO3	The students will be able to understand the drive-train topologies.
	CO4	The students will be able to know about the impacts and developments of electric vehicles.
	CO5	The students will be able to update themselves with the recent researches in electric vehicles.

UNIT I	**Electric and Hybrid Electric Vehicles**	**Periods** : **9**	
Conventional vehicles- basics of conventional vehicle and its performance - History of electric and hybrid electric vehicles - Comparison of EV with internal combustion engine vehicles. Electric vehicle- introduction- working- need for electric vehicle- types- Hybrid electric vehicle- introduction- types.			**CO1**
UNIT II	**Components and Energy Storage Systems**	**Periods** : **9**	
Introduction to electrical components used in hybrid and electric vehicles. Electric vehicle storage technology – Different types of batteries for electric vehicles – Basic battery parameters – Battery modeling and equivalent circuit – Methods of electric vehicle battery charging – Alternative energy sources – Hydrogen storage systems – Reformers – Supercapacitors/Ultracapacitors - Fuel cell powered vehicles – Flywheel technology.			**CO2**
UNIT III	**Traction in Electric Vehicles**	**Periods** : **9**	
Basic concepts of electric traction, introduction to various electric drive-train topologies, Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis.			**CO3**
UNIT IV	**Design Specifications**	**Periods** : **9**	
Selection of motor and sizing – Selection of power electronics components and sizing – Inverter technology – Design of battery pack and auxiliary energy storage system – Design of ancillary systems – EV recharging and refueling system design.			**CO4**
UNIT V	**Review on Electric Vehicles**	**Periods** : **9**	
Impacts of EV- Emerging fuels and technologies-EV trends and developments- Future improvements- improved batteries, battery management and intermediate storage - Traction motors- Power flow- Control techniques- researches and developments in electric vehicles.			**CO5**

Lecture Periods: 45	**Tutorial Periods:15**	**Practical Periods: -**	**Total Periods:60**

Reference Books :

1. M.Ehsani, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2005.
2. Ali Emadi, Advanced Electric Drive Vehicles, CRCPress,2014.
3. K. T. Chau, ‘Electric vehicle machines and drives: Design, analysis and application’, first edition, John Willey and Sons Singapore pte. ltd., 2015.
4. M. Ehsani, Y. Gao and A. Emadi, ‘Modern electric, hybrid electric and fuel cell vehicles: Fundamentals, Theory and design’, second edition, CRC press, 2011.
5. Larminie and J. Lowry, ‘Electric vehicle technology explained’, second edition, John Willey and Son ltd., 2012.
6. I. Husain, ‘Electric and hybrid vehicles: Design fundamentals’, CRC press, 2003.

<u>CO – PO Mapping</u>

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1				1	2	1		1			1		2	3	1
CO2				1	2	1		1			1		2	3	1
CO3				1	2	1		1			1		2	3	1
CO4				1	2	1		1			1		2	3	1
CO5				1	2	1		1			1		2	3	1

<u>Score</u>: **3** – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Electrical and Electronics Engineering</td><td colspan="8">Programme: M.Tech (Electric Drives and Control)</td></tr>
<tr><td colspan="2">Semester: Second</td><td colspan="4">Course Category Code: PSE</td><td colspan="4">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>EEZ10</td><td>MODERN POWER ELECTRONIC CONVERTERS</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8">Analysis of Power Converters</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="7">Able to explain the working, performance and applications of modern dc-dc converters.</td></tr>
<tr><td>CO2</td><td colspan="7">Able to understand the performance of recent switched mode ac-dc converters with PFC options.</td></tr>
<tr><td>CO3</td><td colspan="7">Able to analyse and compare the MLI topologies, and also able to explain the principle of boost typed VSIs.</td></tr>
<tr><td>CO4</td><td colspan="7">Able to understand the tenets of recent ac-ac converters with and without dc link.</td></tr>
<tr><td>CO5</td><td colspan="7">Able to understand the different soft switching approaches applicable to power converters.</td></tr>
<tr><td>UNIT I</td><td colspan="5">DC-DC Converters</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Overview and grouping of converters in DC-DC converter family; Isolated DC-DC Converters-Fly-back, Forward, Push pull converter; Pump circuits - developed, transformer type and super lift pumps; Luo converters - positive, negative and double output; Voltage-lift converters and Super lift converters-types and basic circuit operation. SEPIC converter; K-Y converter. Parallel and interleaved operation of converters.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5">AC-DC Converters</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Switched mode ac-dc converters – synchronous rectification, single and three phase topologies, switching techniques; Power factor correction circuits– concept, classification and high frequency topologies for PFC; Vienna rectifier-working, switching strategy and analysis.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5">DC-AC Converters</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">B4 inverter; Multi-level Inverters - concept, classification of multilevel inverters, Principle of operation, main features and analysis of Diode clamped, Flying capacitor and cascaded multilevel inverters; Comparison of topologies – device stress, losses, component count and dc link voltage balancing; Component count reduced topologies. Carrier based modulation schemes of MLI - generation waveforms and harmonic content. Boost type VSIs- Z - Source inverter (ZSI), quasi ZSI (qZSI), switched inductor ZSI (SLZSI), Trans ZSI, r-ZSI.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5">AC-AC Converters With and Without DC Link</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Matrix converters – Bidirectional Switches, topology, operation, modulation techniques (Venturini and SVM), input current harmonics, Commutation and protection issues, Realization of Input Filter, Applications; AC-AC converter with DC link - topologies and operation, performance comparison with matrix converter.</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="5">Soft-Switching Power Converters</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Resonant concept-Hard switched Vs soft switched converters, Switching Loci; ZVS, ZCS, ZVT, quasi-resonance principles; Classification of Resonant Converters; ZCS topologies-buck, boost and buck-boost; ZVS topologies- buck, boost and buck-boost; ZVT and ZCT converters-Switching Transition, ZVT buck; ZCS-QRC.</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="3">Tutorial Periods: -</td><td colspan="2">Practical Periods: -</td><td colspan="2">Total Periods: 45</td></tr>
</table>

Reference Books :

1. Advanced DC/DC Converters, Fang Lin Luo and Fang Lin Luo, CRC Press, New York, 2004.
2. Ali Emadi, Alireza Khaligh, Zhong Nie and Young-Joo Lee, "Integrated Power Electronic Converters and Digital Control", Taylor & Francis Group, 2009.
3. Power Electronics Handbook, M.H.Rashid, Academic press, Newyork, 2000.
4. Issa Batarseh and Ahmad Harb,"Power Electronics-Circuit Analysis and Design", Springer International, Orlando, 2018.
5. Power Electronics Handbook, M.H.Rashid, Academic press, Newyork, 2000.
6. Issa Batarseh, Power Electronic Circuits, John Wiley andSons, Inc.2004.
7. Jai PAgarwal, Power Electronics: Converters, Applications, and Design, 3rd edition, Prentice Hall, 2000.
8. Johann WKolar, UweDrofenik, and Franz C.Zach, “VIENNA Rectifier II—A Novel Single-Stage High-Frequency Isolated Three-Phase PWM Rectifier System”, IEEE Transactions on Industrial Electronics, vol.46, no.4, pp.674-691, August 1999.
9. S.Ramkumar, V.Kamaraj, S.Thamizharasan, S.Jeevananthan, "A New Series Parallel Switched Multilevel DC-Link Inverter Topology", International Journal of Electrical Power and Energy Systems (Elsevier),vol.36,no.1,pp.93-99,2012.
10. B.P.McGrathand D.G. Holmes, "Multicarrier PWM strategies for multilevel inverters", in IEEE Transactions on Industrial Electronics, vol. 49, no. 4, pp. 858-867, Aug. 2002, doi:10.1109/TIE.2002.801073.

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	1	2	1	1	1	2	2	3	2	3	2	2
CO2	3	2	2	1	2	1	1	1	2	2	3	2	3	2	2
CO3	3	2	2	1	2	1	1	1	2	2	3	2	3	2	2
CO4	3	2	2	1	2	1	1	1	2	2	3	2	3	2	2
CO5	3	2	2	1	2	1	1	1	2	2	3	2	3	2	2

Score: **3** – High; **2** – Medium; **1** – Low

Department: **Electrical and Electronics Engineering**			Programme: **M.Tech (Electric Drives and Control)**						
Semester: **Second**			Course Category Code: **PSE**				Semester Exam Type: **TY**		
Course Code	Course Name		Periods / Week			Credit	Maximum Marks		
			L	T	P		CA	SE	TM
EEZ11	**POWER ELECTRONICS IN POWER SYSTEMS**		3	-	-	3	40	60	100
Prerequisite	Power Electronics Engineering								
Course Outcome	**CO1**	Understanding the power system requirements for VAR compensators and their application on load and system to meet the performance regulations and quality.							
	CO2	Ability to apply and determine compensators capacity on load side and system side for given system on VR, PF Correction, Load balancing, power transfer and stability.							
	CO3	Understanding of conventional compensator & their choice, ability to design modern static compensator with their control.							
	CO4	Understanding UPFC to control system real and reactive power, design solid state system for UPFC and tap changing transformer.							
	CO5	Understanding the HVDC types, operation, control and protection. Ability to choose and design converters both conventional and modern for HVDC system.							

UNIT I	**Reactive Power Requirements**	**Periods : 9**
Power system components–representation of single line diagram–uncompensated lines-compensators types and characteristics - conventional compensator - modern compensator – shunt compensator – series compensator –principles of reactive power control–introduction on load compensation-line compensation–P and Q control- phase angle regulation. Compensator to address the power quality issues such as voltage regulation and disturbance, power factor, non-linear loads and harmonics and unbalanced loads. Compensator requirements for solid state converters–determination of input power factor and harmonics for various converters–power factor improvement using Load and forced commutated converters.		**CO1**
UNIT II	**Reactive Power Compensation and Regulation**	**Periods : 9**
Load compensation- voltage regulation - power factor correction - phase balance unsymmetrical loads. Line compensations – increased power transfer capability – stability and transient limit – losses – harmonics - sub synchronous oscillations - mitigations.		**CO2**
UNIT III	**Static Compensators and Components**	**Periods : 9**
Introduction to conventional compensators – synchronous condenser – saturable core reactor. Analysis and design of static compensators - TCR – TSC – SVC –TCSC – modeling and control of static compensators.		**CO3**
UNIT IV	**Design of UPFC and Static Tap Changers**	**Periods : 9**
UPFC components – shunt devices - series devices – operation and control – real and reactive power – UPFC parameters and design philosophy. Conventional tap changing methods – solid state tap changer – voltage regulation -different schemes – comparison – specifications – design methods. UPFC components – shunt devices - series devices – operation and control – real and reactive power – UPFC parameters and design philosophy. Conventional tap changing methods – solid state tap changer – voltage regulation -different schemes – comparison – specifications – design methods.		**CO4**
UNIT V	**HVDC and Static Generator Excitation Systems**	**Periods : 9**
HVDC components-kinds of DC links – HVDC converters – twelve and higher pulse operation - commutation issues – control characteristics – constant phase angle control – constant current and extinction angle control. Introduction to modern converters in Light HVDC, HVDC – protections - reactive power requirements – harmonics– filter types and design of various ac and dc filters. Solid state		**CO5**

excitation of synchronous generators – different schemes – Generator excitation systems – redundancy and reliability.	

Lecture Periods: 45	Tutorial Periods: -	Practical Periods: -	Total Periods: 45

Reference Books :

1. Vijay K. Sood, HVDC and FACTS Controller: Application of Static Converters in power systems, IEEE Power Electronics and Power Systems series, Kluwer Academic publishers, Boston,2004.
2. Narani. G Hingorani and Laszlo Gyugyi, Understanding FACTS, IEEE Power Engineering society sponsor, IEEE, 2000.
3. K.R.Padiyar, Facts Controllers in Power Transmission and Distribution, New Age International (P) Ltd, Publishers, 2007.
4. "A Static alternative to the transformer on load tap changing", IEEE Trans. On PAS, Vol.PAS-99, Jan./Feb.1980,
5. Improvements in Thyristor controlled static on-load tap controllers for transformers, IEEE, Vol. PAS-101, Sept-1982.
6. Shunt Thyristor rectifiers for the Generator Excitation systems", IEEE Trans. On PAS.Vol.PAS-96,July/August,1977.

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	2	1	1	1	1	1	2	2	2	3	1	1
CO2	3	3	3	2	1	1	1	3	1	2	2	2	3	1	1
CO3	3	3	3	2	1	1	1	3	1	2	2	2	3	1	1
CO4	3	3	3	2	1	1	1	3	1	2	2	2	3	1	1
CO5	3	3	3	2	1	1	1	3	1	2	2	2	3	1	1

Score: **3** – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Electrical and Electronics Engineering</td><td colspan="4">Programme: M.Tech (Electric Drives and Control)</td><td colspan="3"></td></tr>
<tr><td colspan="2">Semester: Second</td><td colspan="4">Course Category Code: PSE</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>EEZ12</td><td>POWER QUALITY</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8">Fundamentals of Power Systems and Power Electronics.</td></tr>
</table>

Course Outcome	**CO1**	Ability to list and classify the various power quality issues.
	CO2	Ability to elucidate the concept of power and power factor in supplying non-linear loads.
	CO3	Ability to design the conventional compensation techniques used for power factor correction and load voltage regulation.
	CO4	Ability to describe about active shunt and series compensation techniques used for power factor correction and load voltage regulation.
	CO5	Ability to design a system, components or process to meet desired needs within realistic constraints and to mitigate PQ problems such as economic, environmental, social, ethical, health and safety.

UNIT I	**Introduction**	**Periods** : **9**	
Introduction-Characterization of Electric Power Quality: Transients, short duration and long duration voltage variations, Voltage Imbalance, waveform distortion, Voltage fluctuations, Power frequency variation, Power acceptability curves – power quality problems: poor load power factor, Nonlinear and unbalanced loads, DC offset in loads, Notching in load voltage, Disturbance in supply voltage- Power quality standards.			**CO1**
UNIT II	**Non-Linear loads and Analysis Of Three Phase System**	**Periods** : **9**	
Single phase static and rotating AC/DC converters, Three phase static AC/DC converters, Battery chargers, Arc furnaces, Fluorescent lighting, pulse modulated devices, Adjustable speed drives. True Power Factor- Three-phase Sinusoidal Balanced System-Instantaneous Active and Reactive Powers for Three-phase Circuits.			**CO2**
UNIT III	**Measurement and Analysis Methods**	**Periods** : **9**	
Voltage, Current, Power and Energy measurements, power factor measurements and definitions-Interpretation and analysis of Power Quality Measurements, event recorders, Analysis: Analysis in the periodic steady state, Time domain methods Frequency domain methods: Laplace's, FFT and Wavelet Transform.			**CO3**
UNIT IV	**Conventional Load Compensation Methods**	**Periods** : **9**	
Principle of load compensation and voltage regulation for single phase loads using passive compensator- classical load balancing problem : open loop balancing of delta connected unbalanced load – closed loop balancing- Analysis and Design of Three-Phase Four-Wire Passive Shunt Compensators - Extraction of fundamental sequence component.			**CO4**
UNIT V	**Power Quality Improvement**	**Periods** : **9**	
Utility-Customer interface -Harmonic filters: passive, Active and hybrid filters -Custom power devices: Network reconfiguring Devices, Load compensation using DSTATCOM Voltage regulation using DSTATCOM, protecting sensitive loads using DVR, UPQC –control strategies: P~Q theory, Synchronous detection method. Custom power park –Status of application of custom power devices.			**CO5**
Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books :

1. Arindam Ghosh, Gerard Ledwich, Power Quality Enhancement Using Custom Power Devices, Kluwer Academic Publishers, 2002.
2. G.T.Heydt, Electric Power Quality, McGraw-Hill Professional, 2007.
3. Roger C.Dugan, Mark F.Mc Granaghan, Surya Santos, H.Wayne Beaty, Electrical Power Systems Quality, McGraw Hill, NewDelhi2003.
4. Derek A. Paice, Power electronic converter harmonics, IEEE Press, 1996.
5. C.Sankaran, Power Quality, CRC Press,2002.
6. A.J. Arrillga, Neville.R.Watson, Power system harmonics – John Wiley Publishers, 2002.
7. Math H. Bollen, Understanding Power Quality Problems, IEEE Press, 2000.
8. J. Arrillaga, Power System Quality Assessment, Johnwiley, 2000.

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	3	1	3	1	3	2	1	1	1	1	1	1	2
CO2	1	2	3	1	1	1	1	1	1	1	1	1	2	1	1
CO3	1	3	2	2	1	2	1	1	1	1	1	1	2	2	1
CO4	1	1	1	1	1	3	1	1	2	1	2	3	3	2	1
CO5	1	1	1	3	1	3	1	3	3	3	1	2	3	3	3

Score: **3** – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: Electrical and Electronics Engineering</td><td colspan="7">Programme: M.Tech (Electric Drives and Control)</td></tr>
<tr><td colspan="2">Semester: Third</td><td colspan="4">Course Category Code: PSE</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>EEZ13</td><td>DISTRIBUTED GENERATION AND MICROGRID</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8">Power Conversion Techniques, Electrical Machines</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="7">To learn the basic components of distributed energy sources & storage systems.</td></tr>
<tr><td>CO2</td><td colspan="7">To illustrate the concept of distributed generation &understand the applicable standards for grid integration.</td></tr>
<tr><td>CO3</td><td colspan="7">To understand basic requirements and various issues of DG with grid integration.</td></tr>
<tr><td>CO4</td><td colspan="7">Understand the concepts of micro-grids, energy management & protection methods.</td></tr>
<tr><td>CO5</td><td colspan="7">Understand centralized control and distributed control in micro-grids.</td></tr>
<tr><td>UNIT I</td><td colspan="6">Introduction</td><td colspan="2">Periods : 9</td></tr>
<tr><td colspan="8">Energy Sources and their availability-trends in energy consumption-Review of Solar PV, Wind Energy systems, Fuel Cells, micro-turbines, biomass, small-scale hydroelectric generation- energy storage systems: batteries – ultra capacitors –flywheels.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="6">Distributed Generations (DG)</td><td colspan="2">Periods : 9</td></tr>
<tr><td colspan="8">Concept and topologies, selection of sources. , regulatory standards/ framework - IEEE 1547 Standard for interconnecting distributed generation to electric power systems–DG installation classes, security issues in DG implementations –siting and sizing of DGs –optimal placement.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="6">Grid Integration of Distributed Energy Resources</td><td colspan="2">Periods : 9</td></tr>
<tr><td colspan="8">Basic requirements of grid interconnections –limits on operational parameters – voltage, frequency and THD limits–grid interface–inverter based DGs and rotary machines based DGs-response to grid abnormal operating conditions, islanding issues. Impact of grid integration with NCE sources on existing power system: reliability, stability and power quality issues.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="6">Microgrids</td><td colspan="2">Periods : 9</td></tr>
<tr><td colspan="8">Concept and definition of micro-grid, micro-grid drivers and benefits, types, structure and configuration of micro-grids -AC and DC micro-grids – power electronic interfaces for micro-grids – energy management and protection issues of micro-grid.</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="6">Control and Operation of Microgrid</td><td colspan="2">Periods : 9</td></tr>
<tr><td colspan="8">Grid connected and islanded modes of operation and control-active and reactive power control, anti-islanding schemes: passive, active and communication based techniques, micro-grid communication infrastructure, power quality issues in micro-grids, regulatory standards, micro-grid economics, Introduction to smart micro- grids.</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="3">Practical Periods: -</td><td colspan="2">Total Periods: 45</td></tr>
</table>

Reference Books :

1. H.Lee Willis, Walter G.Scott, 'Distributed Power Generation–Planning and Evaluation', Marcel Decker Press, 2000.
2. M.Godoy Simoes, FelixA Farret, 'Renewable Energy Systems–Design and Analysis with Induction Generators', CRCpress.
3. Math H. Bollen, "Integration of Distributed Generation in the Power System", John Wiley & Sons, 2011.
4. Robert Lasseter, Paolo Piagi, 'Micro-grid: A Conceptual Solution', PESC 2004, June2004.
5. F. Katiraei, M.R. Iravani, 'Transients of a Micro-Grid System with Multiple Distributed Energy Resources', International Conference on Power Systems Transients (IPST'05) in Montreal, Canada on June19-23, 2005.
6. Voltage Source Converter in PS: Modeling, Control, Applications, Amirnaser Yezdani, RezaIravani, IEEE Wiley Publishers, 2009.
7. P.Jayaprakash(Author), D.P.Kothari, 'Power Quality and Distributed Generation', Alpha Science International, 2020
8. Power Switching Converters: Medium and High Power, Dorin Neacsu, CRC Press, Taylor & Francis, 2006.
9. Ali Keyhani, Design of Smart Power Grid Renewable Energy Systems, ISBN: 978-0-470-62761-7,Wiley
10. S.Chowdhury, S.P.Chowdhury and P.Crossley, Micro-grids & Active Distributionn/w,ISBN978-1-84919-014-5,IE,2009
11. Gregory W. Massey, "Essentials of Distributed Generation Systems", Jones & Bartlett Publishers, 2011.
12. N. Jenkins, Nicholas Jenkins, "Distributed Generation" IET Press, 2010.
13. S. Chowdhury, P. Crossley, "Micro-grids and Active Distribution Networks", IET Press, 2010.

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	2	2	1	2	2	3	3	1	2	1	1	2	2	3
CO2	1	2	2	1	2	2	3	2	1	2	1	1	1	2	3
CO3	2	2	2	2	3	2	3	2	2	3	1	2	1	3	3
CO4	2	2	2	3	3	3	3	2	2	3	3	2	3	3	3
CO5	2	2	2	3	3	3	3	2	2	3	1	2	2	3	3

Score: **3** – High; **2** – Medium; **1** – Low

Department: **Electrical and Electronics Engineering**	Programme: **M.Tech (Electric Drives and Control)**

Semester: **Third**	Course Category Code: **PSE**	Semester Exam Type: **TY**

Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
EEZ14	**FLEXIBLE AC TRANSMISSION SYSTEM CONTROLLERS**	3	-	-	3	40	60	100

Prerequisite	Nil	
Course Outcome	**CO1**	The students will be able to understand the basics of real and reactive power compensation using conventional compensators.
	CO2	The students will be able to understand different shunt compensation schemes developed using thyristors and their role in enhancing the existing power system.
	CO3	The students will be able to understand different series compensation schemes developed using thyristors in enhancing the power transfer capability of transmission system.
	CO4	The students will be able to comprehend the role of shunt and series compensators developed using voltage source converter.
	CO5	The students will be able to understand the dynamic performance of multifunctional FACTS devices.

UNIT I	**Introduction**	**Periods** : **9**
Review of basics of power transmission networks-control of power flow in AC transmission line-Analysis of uncompensated AC Transmission line- Passive reactive power compensation: Effect of series and shunt compensation at the mid-point of the line on power transfer- Need for FACTS controllers- types of FACTS controllers.		**CO1**
UNIT II	**Thyristor Controlled Shunt Compensator**	**Periods** : **9**
Objective of shunt compensation–Principle and operating characteristics of Thyristor Controlled Reactor (TCR)–Thyristor Switched Capacitor (TSC)–Static VAR Compensators (SVC)–SVC control system–SVC voltage regulator model–Transfer function and dynamic performance of SVC–Transient stability enhancement and power oscillation damping.		**CO2**
UNIT III	**Thyristor Controlled Series Compensator (TCSC)**	**Periods** : **9**
Series compensation–Principles of operation of TCSC–Capability characteristics of TCSC–Modeling of TCSC– TCSC control system– enhancement of system damping– mitigation of sub-synchronous resonance.		**CO3**
UNIT IV	**Voltage Source Converter Based Shunt and Series Compensators**	**Periods** : **9**
Static Synchronous Compensator (STATCOM) - Principle of operation- VI Characteristics-Harmonic performance – Steady state model– Static Synchronous Series Compensator (SSSC)-Principle of operation and characteristics of SSSC–control range and VA rating–capability to provide real power compensation – Internal and External control schemes for SSSC.		**CO4**
UNIT V	**UPFC and IPFC**	**Periods** : **9**
Unified power flow controller (UPFC) - Basic operating principles–conventional transmission control capabilities – Independent Real and reactive power flow control– control structure. Interline power flow controller (IPFC) - Basic operating principles and characteristics – Control structure.		**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books :

1. Narain G.Hingorani and Laszlo Gyugyi, Understanding FACTS concepts and technology of Flexible AC transmission systems, Edition2001, IEEE Power Engineering Society Sponsor, IEEE press, 2001.
2. R.Mohan Mathur and Rajiv K.Varma, Thyristor-Based FACTS Controllers for Electrical Transmission Systems, Edition February 2002, IEEE press-JohnWiley and Sons publications,2002.
3. Yong Hua Song and Allan T Johns, Flexible AC Transmission System (FACTS), IEEE Power Engineering Series IEEE press,1999.
4. Einar V.Larsen, Jaun J. Sanchez-Gasca and Joe H. Chow, Concepts of design of FACTS Controllers to damp power swings, IEEE Transaction on Power Systems, Vol.10, no.2, May1995.
5. GyugyiL, Unified Power flow control concept for flexible AC transmission, IEEE Proceedings, vol.139, no.4, July 1992.

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1				1	2	1		1		1	1		2	3	1
CO2				1	2	1		1		1	1		2	3	1
CO3				1	2	1		1		1	1		2	3	1
CO4				1	2	1		1		1	1		2	3	1
CO5				1	2	1		1		1	1		2	3	1

Score: **3** – High; **2** – Medium; **1** – Low

Department: **Electrical and Electronics Engineering**		Programme: **M.Tech (Electric Drives and Control)**						
Semester: **Third**		Course Category Code: **PSE**				Semester Exam Type: **TY**		
Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
EEZ15	**VARIABLE STRUCTURE SYSTEMS AND SLIDING MODE CONTROL**	3	-	-	3	40	60	100
Prerequisite	Nonlinear Control Systems, Modern Control Theory, Digital Control Systems.							

Course Outcome	**CO1**	The students will be able to acquire knowledge in the method of combining system structures during the control process so as to achieve stability and better dynamic performance characteristics.
	CO2	The students will be able to acquire knowledge of variable structure systems with sliding mode motion so as to design sliding mode controllers for both linear and nonlinear systems so as to achieve desired performance characteristics.
	CO3	The students will be able to understand the design of switching surfaces for higher order systems and design variable structure controllers to take care of possible parameter variations in the system. The students will be able to study the phenomena of chattering and its reduction techniques for implementing the variable structure controllers to physical systems.
	CO4	The students will be able to understand the sliding mode observers and advanced variants of sliding mode control.
	CO5	The students will be able to understand the variable structure model following control systems so as to utilize the merits of model following in variable structure control systems.

UNIT I **Introduction**	**Periods** : **9**	
Introduction to Variable Structure Systems - Synthesis of stable systems from unstable structures -VSS for improving dynamic response of systems - Stability analysis in VSS - simulation of VSS using standard numerical packages.		**CO1**
UNIT II **Sliding Mode Operation**	**Periods** : **9**	
Variable structure systems with sliding mode operation - sliding mode motion- existence condition and equivalent control for sliding mode motion- sliding mode motion on switching line - Invariance conditions. Introduction to discrete-time sliding mode control.		**CO2**
UNIT III **Design of Sliding Mode Controllers**	**Periods** : **9**	
Design of sliding mode controllers using feedback linearization for non-linear dynamic systems - Sliding mode motion on switching surface - Design of stable switching surfaces for nonlinear systems - switching and non-switching based discrete-time sliding mode control. Design of sliding mode controller for higher order systems – Case study: Sliding mode controller design for a robotic manipulator- Chattering phenomena in sliding mode control – Methods to reduce chattering in sliding mode control technique.		**CO3**
UNIT IV **Sliding Mode Observers and Advancements in VSS**	**Periods** : **9**	
Sliding mode observers - Need of sliding mode observers - Design of sliding mode observers – case studies. Sliding mode twisting controller - Super twisting controller -Lyapunov based sliding mode control. Super twisting technique based observers. Applications of sliding mode controllers to electric drives.		**CO4**
UNIT V **Variable Structure Model Following Control**	**Periods** : **9**	
Variable Structure Model Following Control (VSMFC) Systems - Conditions for perfect model and sliding		**CO5**

mode equivalent control - Sliding mode discontinuous control - Design of VSMFC for second order and higher order systems.	

Lecture Periods: 45	Tutorial Periods: -	Practical Periods: -	Total Periods: 45

Reference Books :

1. C. Edwards and Sarah K. Spurgeon, Sliding mode control: Theory and applications. Taylor and Francis; 1998.
2. V. I. Utkin, Sliding Modes in Control Optimization. New York: Springer-Verlag, 1992.
3. U. Itkis, Control Systems of Variable Structure., New York, Wiley, 1976.
4. A. S. I. Zinober, Deterministic Control of Uncertain Systems, British Library, 1990 (Edited Volume).
5. B. Bandyopadhyay and S. Janardhanan, Discrete-time Sliding Mode Control: A Multirate Output Feedback Approach, Lecture Notes in Control and Information Sciences, Springer-Verlag, 2005.

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1		1	3	1		2						2	2	3	
CO2		2	2	1	3							2	1	2	
CO3		3	2	1								2	1	3	
CO4		3	2	1								2	1	2	
CO5		1	1	2	3							2	2	3	

Score: **3** – High; **2** – Medium; **1** – Low