SEMESTER I

Discipline: ELECTRICAL & ELECTRONICS

Stream: EE4 (ELECTRICAL MACHINES)

Course No.	Course Name	L-T-P-Credits	Year of Introduction
221TEE100	LINEAR ALGEBRA AND LINEAR SYSTEMS	3 - 0 - 0	2022

Preamble: Nil

Course Prerequisites

Basic knowledge of engineering mathematics at UG level.

Course Objectives

To equip the student with mathematical techniques necessary for computing applications in engineering systems.

Course Outcomes:

After the completion of the course the student will be able to

CO 1	Explain the concepts of vector spaces.
CO 2	Apply linear transformations in linear systems
CO 3	Solve systems of linear equations and interpret their results
CO 4	Solve LTI and LTV Systems
CO 5	Analyse linear systems.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1			3	2	2	2	
CO 2			3	3	3	2	
CO 3			3	3	3	2	
CO 4			3	3	3	2	
CO 5			3	3	3	2	

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	40%
Analyse	30%
Evaluate	30%
Create	-

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Micro project/Course based project : 20 marks
Course based task/Seminar/Quiz : 10 marks
Test paper, 1 no. : 10 marks

The project shall be done individually. Group projects not permitted. Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

The end semester examination will be conducted by the University. There will be two parts; Part Aand Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solvingM Tech Regulations, Curriculum 2022 and quantitative evaluation), with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks. Total duration of the examination will be 150 minutes

Model Question Paper

Pages **SLOT**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY SECOND SEMESTER B. TECH DEGREE EXAMINATION, MONTH & YEAR

221TEE100: LINEAR ALGEBRA AND LINEAR SYSTEMS

Max. Marks: 60 **Time: 2.5 hrs**

	Part A (Answer all questions)	**Marks**
1	How orthogonality is defined between vectors? Check whether the vectors $v_1 = [1, 2, 1], v_2 = [1, -1, 1]$ are orthogonal or not? If $S = \{v_1, v_2, \dots, v_n\}$ is the set of n mutually orthogonal vectors what is the dimension of the space spanned by the set S? Justify your answer?	(5)
2	Show that null space is the orthogonal complement of row space of a linear transformation matrix	(5)
3	Show that similarity transformation doses not change the Eigen values of a linear transformation matrix	(5)
4	What are Eigen vectors of a linear transformation? Find a non-singular matrix P such that $P^T AP$ is diagonal $A = \begin{bmatrix} 1 & 1 & 2 \\ 0 & 3 & 2 \\ 1 & 3 & 9 \end{bmatrix}$	(5)
5	Derive the expression for the controllability Grammian matrix of a linear system	(5)
	Part B (Answer any five questions)	
6	With the help of a suitable example analyze the stability of a system by pole zero cancellation.	(7)
7	Define inner product space? Consider the following polynomial $P(t)$ with inner product given by $< f, g >= \int_0^1 f(t)g(t)dt$ find i) $< f, g >$ and (ii) $\| f \|, \| g \|$ if $f(t) = t + 2, \quad g(t) = 3t - 2$	(7)

8	Find the Jordan canonical form of the matrix $A = \begin{bmatrix} 2 & 0 & 1 & -3 \\ 0 & 2 & 10 & 4 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 3 \end{bmatrix}$	(7)
9	Explain in detail the separation principle in the design of control systems.	(7)
10	What is the significance of a observability Grammian matrix. Derive the expression for the observability Grammian matrix of a linear system.	(7)
11	What is minimum polynomial of a linear transformation? Find all the Eigen values of $B = \begin{bmatrix} 3 & -1 & 1 \\ 7 & -5 & 1 \\ 6 & -6 & 2 \end{bmatrix}$ what is meant by geometric multiplicity of an Eigen value? Find geometric multiplicity of Eigen values of B?.	(7)
12	Derive the Ackermanns formula to obtain the state feedback gain matrix.	(7)

Text book:

1. Erwin Kreyszig, Advanced Engineering Mathematics 9th Edition, Wiley International Edition Press, Numerical Recipes for scientific computing,
2. Thomas Kailath, Linear Systems

References:

1. Bhaskar Dasgupta, Applied Mathematical Methods, Pearson,
2. Arfken, Weber and Harris, Mathematical Methods for Physicists, A comprehensive guide, 7th Edition, Elsevier, 2013

Syllabus

Module I

Vector Spaces - Spaces and Subspaces, Four Fundamental Subspaces, Spanning sets, Linear Independence, Basis and Dimension

Module II

Linear Transformations – Space of Linear Transformations, Matrix representation of linear transformations, Change of Basis and Similarity

Module III

Solutions to Linear System of Equations, Rectangular Systems and Echelon Forms, Homogeneous and Non homogeneous systems, Eigenvalues, Eigenvectors, Eigenspaces, Diagonalizability.

Module IV

Linear Systems - Solutions to LTI and LTV Systems, Analysis of stabilization by pole zero cancellation - Initial conditions for Analog- Computer Simulation, Controllability, Controllabilty Grammians , Stabilizability, Controllable Subspaces, controllable and uncontrollable modes.

Module V

Reachability and Constructability, Reachable Subspaces, Observability, Observability Grammians, Observable Decomposition, Kalman Decomposition, State feedback Controller Design, Observer Design, separation principle - combined observer controller configuration.

Course Plan

No	Topic	No. of Lectures
1	Vector Spaces	
1.1	Spaces and Subspaces.	1
1.2	Four Fundamental Subspaces	2
1.3	Spanning sets	1

1.4	Linear Independence	2
1.5	Basis and Dimension	2
2	Linear Transformations	
2.1	Space of Linear Transformations	2
2.2	Matrix representation of linear transformations	3
2.3	Change of Basis and Similarity	3
3	Solutions to Linear System of Equations	
3.1	Rectangular Systems and Echelon Forms	2
3.2	Homogeneous and Non homogeneous systems	2
3.3	Eigenvalues, Eigenvectors, Eigenspaces	2
3.4	Diagonalizability	2
4	Linear Systems	
4.1	Solutions to LTI and LTV Systems	2
4.2	Analysis of stabilization by pole zero cancellation - Initialconditions for Analog- Computer Simulation	2
4.3	Controllability, Controllability Grammians , Stabilizability	2
4.4	Controllable Subspaces, controllable and uncontrollable modes	2
5		

5.1	Reachability and Constructability, Reachable Subspaces	1
5.2	Observability, Observability Grammians	1
5.3	Observable Decomposition, Kalman Decomposition	2
5.4	State feedback Controller Design	2
5.5	Observer Design, separation principle - combined observercontroller configuration	2

CODE 221TEE005	COURSE NAME Modeling of Electrical Machines	CATEGORY	L	T	P	CREDIT
		Program Core 1	2	1	0	3

Preamble: This course aims to provide knowledge on the linear transformation of rotating electrical machines and their steady state and transient analysis.

Prerequisites: Nil

Course Outcomes: The COs shown are only indicative. For each course, there can be 4 to 6 COs.

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

CO 1	Develop two-pole model representation of electrical machines.
CO 2	Develop the linear transformation equations of rotating electrical machines incorporating the concept of power invariance
CO 3	Apply linear transformation for the steady state and transient analysis of different types of DC machines.
CO 4	Apply linear transformation for steady state and transient analysis of three-phase synchronous machines.
CO 5	Apply linear transformation for steady-state analysis of three-phase induction machines and double cage induction machines
CO 6	Apply linear transformation for steady-state analysis of single-phase induction machines.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	2		3	3			
CO 2	2		3	3			
CO 3	2		3	3			
CO 4	2		3	3			
CO 5	2		3	3			
CO 6	2		3	3			

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	30%
Analyse	50%
Evaluate	20%
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Micro project/Course based project : 20 marks
Course based task/Seminar/Quiz : 10 marks
Test paper, 1 no. : 10 marks
The project shall be done individually. Group projects not permitted. Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question. Part B will contain 7 questions with a minimum of one question from each module of which students should answer any five. Each question can carry 7 marks.

Model Question paper

QP CODE: PAGES:2

Reg. No:_______________ Name:_______________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
FIRST SEMESTER M. TECH DEGREE EXAMINATION,
MONTH & YEAR

Course Code: **221TEE005**

Course Name: **Modeling of Electrical Machines**

Max. Marks: 60 Duration: 2.5 Hours

Part A

(Answer all questions)

1. Describe the importance of the per-unit system in the generalized machine theory and develop an expression for the self-inductance of two mutually coupled coils (5)
2. Derive the transformed impedance and connection matrix in series coupled coils (5)
3. Obtain the voltage equations of the dc series motor from its generalized mathematical model (5)
4. Derive and draw the phasor diagram of the synchronous generator (5)
5. Explain the double field theory as applied to single phase induction machine (5)

Part B

(Answer any five questions)

6. What is Krone's primitive machine? Obtain an expression for the electrical torque of Krone's primitive machine and show that no torque is produced by the interaction between flux and current on the same axis. (7)
7. Explain Park transformation deriving the transformation for currents between 3 phase rotating axes to 2 phase stationary axes (7)
8. Analyse separately excited dc generator under the transient condition of application of sudden short circuit (7)
9. Write the impedance matrix for a 3-phase salient pole synchronous machine. Hence obtain an expression for instantaneous electromagnetic torque and identify the various terms in it (7)
10. Obtain the equivalent circuit of three phase induction machine from the primitive model (7)
11. Obtain the transfer function and draw the block diagram of separately excited dc generator (7)
12. Apply cross field revolving theory and conduct steady-state analysis of single-phase induction machine (7)

SYLLABUS

MODULE 1

Basic two pole model of rotating machine: - per unit system, transformer and rotational voltages in the armature, Kron's Primitive machine – leakage flux, voltage and torque equations, resistance, inductance, and torque matrix. (6hours)

MODULE 2

Linear transformation in machines: - Invariance of power, transformation from a displaced brush axis, transformation from three phase to two phase, rotating axes to stationary axes. Park's Transformation-Physical concept. Transformed impedance matrix, Electrical torque. Restrictions of the Generalized theory of machines. (7hours)

MODULE 3

DC Machines: Application of generalized theory to separately excited, shunt, series, and compound machines- Steady state and transient analysis, transfer functions. Generator operation with displaced brushes, generator operation on no load and load. sudden short circuit of separately excited d.c generator. sudden application of inertia load to separately excited dc motor(Numerical problems from relevant topic)

(8hours)

MODULE 4

Synchronous Machines: synchronous machine parameters, Primitive machine model of synchronous machine with damper windings on both axes. Balanced steady-state analysis-power angle curves. Transient analysis- sudden three-phase short circuit at generator terminals – armature currents and torque - Transient power angle curve. Phasor diagrams under transient and sub-transient conditions. synchronous machine reactance and time constants- Sudden reactive loading and unloading (numerical problems)

(11 hours)

MODULE 5

Induction Machines: Primitive machine representation, Transformations- Steady state operation-Equivalent circuit Torque slip characteristics- Double cage rotor representation Equivalent circuit. Induction machine dynamics -starting and braking. Accelerating time Single phase induction motor- Revolving Field Theory, equivalent circuit- Voltage and Torque Equations-Cross field theory- AC Commutated machines- single phase series motor and repulsion motor- generalized model only.

(8 hours)

COURSE PLAN

(For 3 credit courses, the content can be for 40 hrs and for 2 credit courses, the content can be for 26 hrs. The audit course in the third semester can have content for 30 hours).

No	Topic	No. of Lectures-40
1	**Basic two-pole model**	
1.1	Basic two pole model: Commutator machine, DC compound machines, shunt machine with interpoles, single phase ac series machine, Repulsion motor, synchronous machine with or without dampers, three-phase induction machines, Amplidyne	2
1.2	Per unit system, transformer and speed voltages in the armature.	2
1.3	Kron's primitive machine- basic 2 pole representation, leakage flux, voltage and torque equations, matrix form.	2
2	**Linear transformation in machines**	
2.1	Linear transformation in machines: Invariance of power, transformation from a displaced brush axis, transformation from three phase to two phase	2
2.2	Rotating axes to stationary axes. Park's Transformation-Physical concept.	3
2.3	Transformed impedance matrix, Electrical torque. Restrictions of the Generalized theory of machines.	2
3	**DC Machines**	
3.1	Application of generalized theory to separately excited, shunt, series and compound machines- Steady state and transient analysis, transfer functions	4
3.2	Generator operation with displaced brushes, generator operation on no load and load.	1
3.3	sudden short circuit of separately excited d.c generator. sudden application of inertia load to separately excited dc motor	3
4	**Synchronous Machines**	
4.1	synchronous machine parameters, Primitive machine model with damper windings on both axes. Balanced steady state analysis-power angle curves.	3
4.2	Transient analysis: sudden three phase short circuit at generator terminals – armature currents and torque, Transient power angle curve. Phasor diagrams under transient and sub transient conditions.	4
4.3	synchronous machine reactance and time constants, Sudden reactive loading and unloading	4
5	**Induction Machines**	
5.1	Primitive machine representation, Transformations- Steady state operation, Equivalent circuit, Torque slip characteristics.	3
5.2	Double cage rotor representation Equivalent circuit. Induction machine dynamics -starting and braking. Accelerating time	2
5.3	Single phase induction motor: Revolving Field Theory, equivalent circuit, Voltage and Torque Equations, Cross field theory.AC Commutator machines: single phase series motor	3

	and repulsion motor (generalized model only).	

Reference Books

1. 1. P. S. Bhimbra, 'Generalized Theory of Electrical Machines', Khanna Publishers, 2002
2. Charles V. Johnes, 'Unified Theory of Electrical Machines'
3. Adkins, Harley, 'General theory of ac machines'
4. C. Concordia, 'Synchronous Machines'.
5. M. G. Say, 'Introduction to Unified Theory of Electrical Machines'
6. E. W. Kimbark, 'Power System Stability - Vol. II'

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221TEE006	POWER ELECTRONIC CIRCUITS	PROGRAM CORE 2	3	0	0	3

Preamble: This course intends to provide in-depth knowledge of different power semiconductor devices and a detailed analysis of various power converters.

Prerequisites: Nil

Course Outcomes: The COs shown are only indicative. For each course, there can be 4 to 6 COs.
After the completion of the course, the student will be able to

CO 1	Select appropriate power semiconductor switches for a particular application based on their functional requirement.
CO 2	Analyse the performance of DC/DC converters with and without isolation.
CO 3	Analyse the performance of switched-mode inverters.
CO 4	Develop the advanced PWM techniques for different power electronic circuits.
CO 5	To analyse the performance of AC-to-AC converters.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	2		3	3	2	2	
CO 2	3	2	3	3	3	2	
CO 3	3	2	3	3	3	2	
CO 4	3	2	3	3	3	2	
CO 5	3	2	3	3	3	2	
CO 6							

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	60%
Analyse	20%
Evaluate	20%
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:
Micro project/Course based project: 20 marks
Course-based task/Seminar/Quiz: 10 marks
Test paper, 1 no: 10 marks
The project shall be done individually. Group projects are not permitted. The test paper shall include a minimum of 80% of the syllabus.

End Semester Examination Pattern:
The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and

maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving M Tech Regulations, Curriculum 2022 7 and quantitative evaluation), with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks. Total duration of the examination will be 150 minutes.

Model Question paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION

Branch: Electrical & Electronics Engineering

221TEE006 POWER ELECTRONIC CIRCUITS

Answer all questions from Part A and any five questions from Part B

Max. Marks: 60 **Duration: 2 hours 30 minutes**

	Part A- Answer All Questions	**Mark**	
1	Explain the features of ideal switches and practical switches.	**5**	
2	A buck convertor has an input voltage of 12V and output voltage of 5V and the peak to peak output voltage ripple voltage is 20mV. The switching frequency is 25 kHz. If the peak to peak ripple current of inductor is limited to 0.8A, determine i)Duty ratio ii) The filter inductance, L iii)The filter capacitor C.	**5**	
3	Explain how the voltage is controlled in single phase inverter using sine triangle PWM.	**5**	
4	Explain diode clamped 3-level inverter configuration. Draw gate signals and inverter terminal voltage of one phase.	**5**	
5	A single-phase AC voltage controller supplies R load, the input supply is 120 V RMS and the load has R = 10 Ω. The thyristor switch is on for 25 cycles and off for 75 cycles. Determine i). RMS output voltage, ii). Input power factor iii). RMS Value of thyristor current. iv). Average thyristor current.	**5**	
	Part B- Answer Any five questions		
6	Explain static and dynamic characteristics of Power MOSFET.	**7**	
7	Describe the operation of a flyback convertor with circuit diagram and relevant waveforms. Derive the expression for voltage conversion ratio.	**7**	
8	Describe the operation of a forward convertor with circuit diagram and relevant waveforms. Derive the expression for voltage conversion ratio.	**7**	
9	Explain the working of a current controlled VSI with hysteresis control scheme.	**7**	
10	Explain the operation of three phase voltage source inverter with 120°conduction mode with the help of circuit diagram and relevant waveforms.	**7**	
11	Explain flying capacitor multilevel inverter topology. Compare it with other multilevel inverter topologies.	**7**	

12	Describe the working of a two stage sequence control of voltage controller for R load. What is the advantage of this controller over single phase full wave voltage controller?	**7**	

SYLLABUS

MODULE 1 (7 hours)

Overview of Power Electronic Elements:- Ideal and Real switches, Switching constraints in power electronic circuits, Types of real switches-Power diodes, Power Transistors, Power MOSFETS, IGBTs - Static and Dynamic Performance, Over voltage Snubbers for switching devices.

MODULE 2 (8 hours)

DC-DC converters:- Buck, boost, buck-boost, and Ćuk converter Topologies, Steady state analysis in continuous conduction mode using inductor volt-sec balance, current and voltage ripples, (Numerical Problems) Design relations for inductor and capacitors, Discontinuous Conduction Mode operation of basic buck and boost converter, Isolated DC-DC converters: Steady-state analysis of flyback, forward converter topologies.

MODULE 3 (8 hours)

Switched Mode Inverters: -Topologies of single-phase half-bridge, full-bridge, and three-phase bridge Voltage Source Inverters- Stepped wave and PWM operation- Sine Triangle PWM- Choice of carrier frequency in SPWM, Bipolar and Unipolar Switching in SPWM, Selective Harmonic Elimination, Current Source Inverters: Analysis of capacitor commutated single phase CSI feeding resistive and pure-inductor loads.

MODULE 4 (8 hours)

Multi-Level Inverters:- Multi-Level Inverters of Diode Clamped Type and Flying Capacitor Type and suitable modulation strategies -Space Vector Modulation – Minimum ripple current PWM method. Multi-level inverters of Cascade Type. Current Regulated Inverter –Current Regulated PWM Voltage Source Inverters, Principles of Current-Controlled VSI- Hysteresis control and PWM current control.

MODULE 5 (8 hours)

AC voltage controllers & Cycloconverters: - Analysis of single-phase ac voltage controller with R and RL load, Performance parameters(Numerical problems), Sequential control of single-phase ac voltage controllers. Single phase step-up and step-down cyclo- convertors, Midpoint and bridge type.

Course Plan (For 3 credit courses, the content can be for 40 hrs, and for 2 credit courses, the content can be for 26 hrs. The audit course in the third semester can have content for 30 hours).

No	Topic	No. of Lectures
1	**Overview of Power Electronic Elements (8 hours)**	
1.1	Ideal and Real switches, Switching constraints in power electronic circuits	2
1.2	Types of real switches-Power diodes, Power Transistors, Power MOSFETS, IGBTs	3
1.3	Static and Dynamic Performance, Over voltage Snubbers for switching devices	3
2	**DC-DC Converters (8 hours)**	
2.1	DC-DC converters: Buck, boost, buck-boost and Ćuk converter Topologies, Steady state analysis in continuous conduction mode using inductor volt-sec balance, current and voltage ripples (Numerical Problems)	3
2.2	Design relations for inductor and capacitors. Discontinuous Conduction Mode operation of basic buck and boost converter.	2
2.3	Isolated DC-DC converters: Steady-state analysis of flyback, forward convertor topologies	3
3	**Switched Mode Inverters (8 hours)**	
3.1	Switched Mode Inverters: Topologies of single-phase half-bridge, full-bridge and three-phase bridge Voltage Source Inverters	3
3.2	Stepped wave and PWM operation- Sine Triangle PWM- Choice of carrier frequency in SPWM, Bipolar and Unipolar Switching in SPWM , Selective Harmonic Elimination	2
3.3	Current Source Inverters: Analysis of capacitor commutated single phase CSI feeding resistive and pure-inductor loads.	3
4	**Multi-Level Inverters (8 hours)**	
4.1	Multi-Level Inverters of Diode Clamped Type and Flying Capacitor Type and suitable modulation strategies -Space Vector Modulation – Minimum ripple current PWM method.	3
4.2	Multi-level inverters of Cascade Type. Current Regulated Inverter – Current Regulated PWM Voltage Source Inverters	2
4.3	Principles of Current-Controlled VSI- Hysteresis control and PWM current control.	3
5	**AC voltage controllers & Cycloconverters (8 hours)**	
5.1	AC voltage controllers: Analysis of single-phase ac voltage controller with R and RL load, Performance parameters (Numerical problems)	3
5.2	Sequential control of single-phase ac voltage controllers.	2
5.3	Cyclo converters: Single phase step up and step down cycloconvertors, Midpoint and bridge type	3

Reference Books

1. Ned Mohan, et al., Power Electronics: Converters, Design and Applications, Wiley
2. Joseph Vithayathil, “Power Electronics: Principles and Applications”, Tata McGraw Hill.
3. V. Ramanarayanan, “Course Notes on Switched Mode Power Converters”, Department of Electrical Engineering, Indian Institute of Science, Bangalore.
4. G. K. Dubey, et.al., “Thyristorised Power Controllers”, New Age International
5. Bin Wu, High Power Converters and AC Drives, IEEE Press, Wiley Interscience, 2006.
6. Rashid “Power Electronics” Prentice Hall India 2007.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221EEE025	SPECIAL ELECTRICAL MACHINES	PROGRAM ELECTIVE 1	3	0	0	3

Preamble: This course aims to provide knowledge on the construction, operation, and control of various Special Electrical Machines.

Prerequisites: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Explain the performance characteristics of Synchronous Reluctance Motors
CO 2	Analyse the performance characteristics and drive circuits for Switched Reluctance Motors
CO 3	Explain the construction and performance characteristics of Stepper Motor and Linear Motors
CO 4	Analyse the performance characteristics and drive circuits for BLDC motor
CO 5	Analyse the performance characteristics and drive circuits for PMSM

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	-	-	3	3	2	2	-
CO 2	-	-	3	3	2	2	-
CO 3	-	-	3	3	2	2	-
CO 4	-	-	3	3	2	2	-
CO 5	-	-	3	3	2	2	-

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	80%
Analyse	20%
Evaluate	-
Create	-

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed Original publications (minimum 10 publications shall be referred)	:	15 marks
Course based task/Seminar/Data collection and interpretation	:	15 marks
Test paper, 1 no.	:	10 marks

Test paper shall include minimum 80% of the syllabus

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to heoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question paper

No. of Pages: 2 **SLOT: D**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR
Branch: **Electrical and Electronics**
221EEE025 - Special Electrical Machines

Max. Marks: 60 Duration: 2.5 hours

Part A
(Answer all questions)

1.	Draw and explain the equivalent circuit and phasor diagram for Synchronous Reluctance Motor.	(5)
2.	Explain the structure and principle of operation of Switched Reluctance Motor.	(5)
3.	Derive the thrust equation of linear induction motor.	(5)
4.	List the advantages and disadvantages of Brushless DC Motor.	(5)
5.	Draw the circuit diagram and explain the torque equation of PMSM.	(5)

Part B
(Answer any five questions)

6. a)	Explain classification of synchronous reluctance motor.	(4)
b)	Explain the Pull-in characteristics of synchronous reluctance motor.	(3)
7. a)	Draw and explain classical bridge converter configuration for three phase SRM	(4)
b)	List the advantages of Switched Reluctance Motor?	(3)
8.	Derive the expression for torque developed in SRM and Explain the process of torque generation	(7)
9. a)	Explain the types of windings used in stepper motor.	(4)
b)	Compare the features of variable reluctance stepper motors and permanent magnet stepper motors.	(3)
10.	With a neat circuit diagram and waveforms, explain commutation sequence of BLDC motor drive.	(7)
11.	Explain the constructional details of Linear Induction Motor and Linear Synchronous Motor	(7)
12.	Explain the construction and working principle of Permanent Magnet Synchronous Motor	(7)

SYLLABUS

MODULE 1

Reluctance Motors: - Principle of Operation-Classification Synchronous Reluctance Motors: Conventional and special types of rotor construction, analysis and equivalent circuit-phasor diagram, Circular loci of current and voltage components, maximum power factor-power expression Pull-in characteristics-factors affecting pulling in- applications.

MODULE 2

Switched Reluctance Motors: - Principle of Operation- structure-inductance profile, Torque production-static and dynamic-Energy conversion loops-partition of energy and effects of saturation-Classical bridge converter and control, Torque/speed characteristics- Rotor position sensing methods - Sensor, sensor - less - comparison

MODULE 3

Linear Motors and Stepper Motors: - Linear induction motor-construction- different types- thrust equation of LIM-end effect -goodness factor, Linear synchronous motors- types and construction of LSM-thrust equation- applications, Stepper Motors: construction-theory of operation-windings in stepper motor-no of teeth-steps per revolution and no of poles- monofilar and bifilar windings-modes of the excitation-torque equation- static and dynamic characteristics.

MODULE 4

Brushless DC motors: - Construction, types, torque generation, principle of operation- Motor characteristics-torque equation, position sensing, Drive circuits -power circuits- variable speed operation, applications.

MODULE 5

Permanent Magnet Synchronous Machine: - Construction- principle of operation-types-EMF equation of PMSM- Torque equation- phasor diagram, Control and characteristics- advantages-applications.

Course Plan

(For 3 credit courses, the content can be for 40 hrs, and for 2 credit courses, the content can be for 26 hrs. The audit course in the third semester can have content for 30 hours).

No	Topic	No. of Lectures
1	**Reluctance Motors (9 Hrs)**	
1.1	Principle of Operation-Classification Synchronous Reluctance Motors: Conventional and special types of rotor construction, analysis and equivalent circuit-phasor diagram	4
1.2	Circular loci of current and voltage components, maximum power factor-power expression	3
1.3	Pull-in characteristics-factors affecting pulling in- applications	2
2	**Switched Reluctance Motors (7 Hrs)**	
2.1	Principle of Operation- structure-inductance profile	2
2.2	Torque production- static and dynamic-Energy conversion loops-partition of energy and effects of saturation-Classical bridge converter and control	3
2.3	Torque/speed characteristics- Rotor position sensing methods - Sensor, sensorless - comprison	2
3	**Linear Motors and Stepper Motors (8 Hrs)**	
3.1	Linear induction motor-construction- different types- thrust equation of LIM-end effect -goodness factor	2
3.2	Linear synchronous motors- types and construction of LSM-thrust equation- applications	2
3.3	Stepper Motors: construction-theory of operation-windings in stepper motor- no of teeth-steps per revolution and no of poles- monofilar and bifilar windings-modes of excitation-torque equation- static and dynamic characteristics	4
4	**Brushless DC motors (8 Hrs)**	
4.1	Construction, types, torque generation, principle of operation	3
4.2	Motor characteristics-torque equation, position sensing,	2
4.3	Drive circuits -power circuits- variable speed operation, applications.	3
5	**Permanent Magnet Synchronous Machine (8 Hrs)**	
5.1	Construction- principle of operation-types-EMF equation of PMSM	3
5.2	Torque equation- phasor diagram	2
5.3	Control and characteristics- advantages- applications.	3

Reference Books

1. Gene F. Franklin, J. David Powell, Michael Workman, "Digital Control of Dynamic Systems", Pearson, Asia
2. T. J. E. Miller, 'Brushless PM and Reluctance Motor Drives', C. Larendon Press, Oxford
3. Takashi Kenjo, 'Stepping Motor and Microprocessor Control', Oxford Science Publications
4. Vienott & Martin, 'Fractional & Sub-fractional hp Electric Motors', McGraw-Hill International Edn.
5. Bimal K. Bose, 'Modern Power Electronics & AC Drives'. Prentice Hall India Ltd.
6. Sake Yamamura, 'Theory of Linear Induction motors', University of Tokyo press
7. Irving L. Kossow, 'Electrical Machinery & Transformers ', Oxford Science Publications

8. Theodore Wildi, Electric Machines, Drives & Power Systems, Prentice Hall India Ltd.
9. E. V. Armensky& G. B. Falk, ‘Fractional hp Electric Machines’, MIR Publishers
10. Laithwaite, ‘Induction Machine for Special Purposes

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221EEE100	Advanced Power Semiconductor Devices	PROGRAM ELECTIVE 1	3	0	0	3

Preamble: Power semiconductor devices are recognized as a key component for all power electronic systems. This course explores the underlying physics and electrical characteristics of power semiconductor devices. The course includes the study of basic silicon devices and the new generation wide band gap devices. After the completion of the course, students will be able to select suitable power semiconductor devices and design gate drive & protection circuits.

Course Outcomes:
After the completion of the course the student will be able to

CO 1	Develop an in-depth knowledge about important Silicon(Si) power semiconductor devices.
CO 2	Analyse the characteristics and operational features of the selected power semiconductor device.
CO 3	Investigate the properties of wide bandgap devices for power electronic applications.
CO 4	Familiarize the students with advanced power electronic devices for different applications.
CO 5	Design gate driver and protection circuits for power electronic switching devices.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3	2	3	2	2	2	1
CO 2	3	2	3	2	2	2	1
CO 3	3	2	3	3	2	3	1
CO 4	3	3	3	3	3	2	1
CO 5	3	2	3	2	2	3	1

PROGRAM OUTCOMES – PO

Outcomes are the attributes that are to be demonstrated by a graduate after completing the programme

PO1: An ability to independently carry out research/investigation and development work in engineering and allied streams

PO2: An ability to communicate effectively, write and present technical reports on complex engineering activities by interacting with the engineering fraternity and with society at large.

PO3: An ability to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

PO4: An ability to apply stream knowledge to design or develop solutions for real world problems by following the standards

PO5: An ability to identify, select and apply appropriate techniques, resources and state-of-the-art tool to model, analyse and solve practical engineering problems.

PO6: An ability to engage in life-long learning for the design and development related to the stream related problems taking into consideration sustainability, societal, ethical and environmental aspects

PO7: An ability to develop cognitive load management skills related to project management and finance which focus on Entrepreneurship and Industry relevance.

Assessment Pattern

Bloom's Category	**End Semester Examination**
Apply	40 %
Analyse	30 %
Evaluate	20 %
Create	10%

Mark distribution

Total Marks	**CIE**	**ESE**	**ESE Duration**
100	40	60	2.5 hours

Evaluation shall only be based on application, analysis or design based questions (for both internal and end semester examinations).

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: 40 marks

- Preparing a review article based on peer reviewed Original publications (minimum 10 publications shall be referred) : 15 marks
- Course based task/Seminar/Data collection and interpretation : 15 marks
- Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Syllabus and Course Plan (For 3 credit courses, the content can be for 40 hrs).

MODULE	COURSE CONTENT (40 hrs)	HRS
I	**Power switching devices- overview-** ideal and typical power devices -characteristics- static and dynamic – unipolar and bipolar power devices - conduction and switching losses- thermal protection- heat sink selection- EMI due to switching- reduction of EMI **Silicon Power Diodes-** Types, forward and reverse characteristics, switching characteristics -losses- ratings –schottky diodes. **Gate Turnoff Thyristor (GTO)** - Basic structure and operation - comparison with thyristors- switching Characteristics - turn-on and Turn-off Transients - gate drive requirements- snubber requirements **Integrated gate-commutated thyristors (IGCTs)-** device types- operation- turn on and turn off behaviour- applications	8
II	**Current-Controlled Devices:** BJTs- Constructional features and operation, static characteristics, switching characteristics- Secondary Breakdown - Safe Operating Area - Darlington Configuration- Comparison with GTO **Voltage-controlled Devices:** Power MOSFETs and IGBTs- basic device physics- principle of operation- construction, types, static and switching characteristics.	8
III	**Wide band-gap devices** – Introduction - advantages over silicon devices – properties of wide band-gap devices - power density of wide bandgap devices- comparison- applications **Silicon carbide (SiC) power diodes-** Advantages- features- properties- comparison with Si power diodes **-** SiC Shottky diode- advantages **Silicon Carbide BJT** – Structure – Operation – Static and Dynamic Characteristics. **Silicon Carbide MOSFET** – Planar Power MOSFETs – Trench Gate Power MOSFETs – Structure – static and dynamic characteristics.	8
IV	**Silicon Carbide IGBT:** n-Channel Asymmetric Structure - Optimized n-Channel asymmetric structure - p-Channel asymmetric structure- blocking characteristics- On-state voltage Drop - turn-off characteristics- switching energy - losses- maximum operating frequency **Gallium Nitride devices** – Vertical Power Hetero junction Field Effect Transistor (HFETs) – Lateral Power Hetero junction Field Effect Transistor (HFETs) - High Electron Mobility Transistors (HEMT) - Static and dynamic characteristics	8
V	**Gate drive and Protection Circuits:** Gate drive circuits for transistors, MOSFET, IGBT, SiC MOSFET and IGBT and GaN devices– challenges and design - necessity of isolation- pulse transformer- optocoupler - overvoltage, over current and gate protection- turn-on and turn-off snubber circuit design **Power modules-** typical internal structure- design challenges- features- design for reliability enhancement- intelligent power modules (IPM)- features- study of typical power modules and IPM	8

Course Plan

No	Topic	No. of Lectures
1	**Power switching devices- overview**- ideal and typical power devices -characteristics- static and dynamic – unipolar and bipolar power devices -conduction and switching losses- thermal protection- heat sink selection- EMI due to switching- reduction of EMI **Silicon Power Diodes**- Types, forward and reverse characteristics, switching characteristics -losses- ratings –schottky diodes **Gate Turnoff Thyristor (GTO)** - Basic structure and operation -comparison with thyristors- switching Characteristics - turn-on and Turn-off Transients - gate drive requirements- snubber requirements **Integrated gate-commutated thyristors (IGCTs)-** device types- operation- turn on and turn off behaviour- applications	
1.1	**Power switching devices- overview**- ideal and typical power devices -characteristics- static and dynamic	1
1.2	Unipolar and bipolar power devices - conduction and switching losses- thermal protection- heat sink selection-	1
1.3	EMI due to switching- reduction of EMI	1
1.4	**Silicon Power Diodes**- Types, forward and reverse characteristics, switching characteristics -losses- ratings –schottky diodes	1
1.5	**Gate Turnoff Thyristor (GTO)** - Basic structure and operation - comparison with thyristors- switching Characteristics - turn-on and Turn-off transients - gate drive requirements- snubber requirements	2
1.6	**Integrated gate-commutated thyristors (IGCTs)-** device types- operation- turn on and turn off behaviour- applications	2
2	**Current-Controlled Devices:** BJTs- Constructional features and operation, static characteristics, switching characteristics- Secondary Breakdown - Safe Operating Area - Darlington Configuration - Comparison with GTO **Voltage-controlled Devices:** Power MOSFETs and IGBTs- basic device physics- principle of operation- construction, types, static and switching characteristics.	
2.1	**Current-Controlled Devices:** BJTs- Constructional features and operation, static characteristics, switching characteristics	2
2.2	Secondary Breakdown in BJT - Safe Operating Area - Darlington Configuration - Comparison with GTO	2
2.3	**Voltage-controlled Devices:** Power MOSFETs and IGBTs- basic device physics- principle of operation-	2
2.4	Construction, types, static and switching characteristics	2
3	**Wide band-gap devices** – Introduction - advantages over silicon devices – properties of wide band-gap devices - power density of wide bandgap devices- comparison- applications **Silicon carbide (SiC) power diodes-** Advantages- features- properties- comparison with Si power diodes **-** SiC Shottky diode- advantages **Silicon Carbide BJT** – Structure – Operation – Static and Dynamic Characteristics. **Silicon Carbide MOSFET** – Planar Power MOSFETs – Trench Gate Power MOSFETs – Structure – static and dynamic characteristics.	
3.1	**Wide band-gap devices** – Introduction - advantages over silicon devices – properties of wide band-gap devices - power density of wide bandgap devices- comparison- applications	2
3.2	**Silicon carbide (SiC) power diodes-** Advantages- features- properties- comparison with Si power diodes**-** SiC Shottky diode- advantages	2

3.3	**Silicon Carbide BJT** – Structure – Operation – Static and Dynamic Characteristics	2
3.4	**Silicon Carbide MOSFET** – Planar Power MOSFETs – Trench Gate Power MOSFETs – Structure – static and dynamic characteristics	2
4	**Silicon Carbide IGBT:** n-Channel Asymmetric Structure - Optimized n-Channel asymmetric structure - P-Channel asymmetric structure- blocking characteristics- On-state voltage Drop - turn-off characteristics- switching energy - losses- maximum operating frequency **Gallium nitride devices** –Vertical Power Hetero junction Field Effect Transistor (HFETs) – Lateral Power Hetero junction Field Effect Transistor (HFETs) - High Electron Mobility Transistors (HEMT) - Static and dynamic characteristics.	
4.1	**Silicon Carbide IGBT:** n-Channel Asymmetric Structure - Optimized n-Channel asymmetric structure -	2
4.2	P-channel asymmetric structure- blocking characteristics- On-state voltage Drop - turn-off characteristics-	1
4.3	Switching energy - losses- maximum operating frequency	1
4.4	**Gallium nitride devices** – Vertical Power Hetero junction Field Effect Transistor (HFETs) – Lateral Power Hetero junction Field Effect Transistor (HFETs)	2
4.5	High Electron Mobility Transistors (HEMT) - Static and dynamic characteristics	2
5	**Gate drive and Protection Circuits:** Gate drive circuits for transistors, MOSFET, IGBT, SiC MOSFET and IGBT and GaN devices– challenges and design - necessity of isolation- pulse transformer- optocoupler - overvoltage, over current and gate protection- turn-on and turn-off snubber circuit design **Power modules**- typical internal structure- design challenges- features- design for reliability enhancement- intelligent power modules (IPM)- features- power modules and IPM	
5.1	**Gate drive and Protection Circuits:** Gate drive circuits for transistors, MOSFET, IGBT, SiC MOSFET and IGBT and GaN devices– challenges and design	2
5.2	Necessity of isolation- pulse transformer- optocoupler overvoltage, over current and gate protection	1
5.3	turn-on and turn-off snubber circuit design	2
5.3	**Power modules**- typical internal structure- design challenges- features- design for reliability enhancement	2
5.4	Intelligent power modules (IPM)- features- study of typical power modules and IPM	1

REFERENCES:

1) B. W. Williams, “Power Electronics- Devices, Drivers, Applications and passive components”, Macmillan, 2005
2) B. Jayant Baliga, “ Fundamentals of Power Semiconductor devices”, Springer, 2019
3) Francesco Iannuzzo, “Modern Power Electronic Devices_ Physics, Applications, and Reliability”, Institution of Engineering & Technology (IET), 2020
4) Mohan, Undeland and Robins, “Power Electronics- Concepts, Applications and Design”, John Wiley and sons, Singapore, 2000

Model Question paper
APJ Abdul Kalam Technological University
First Semester M. TECH Degree Examination Month &

Year221EEE100– ADVANCED POWER SEMICONDUCTOR

DEVICES

Time: 3 hrs. Max.Marks:60

PART A (5X5=25 marks)

1. Discuss the factors to be considered for the selection and power handling capability of power semiconductor devices

2. What are the differences between current controlled and voltage-controlled devices in terms of gate drive design? Explain

3. What are wide band gap devices and what are the advantages over silicon devices? Explain

4. What are the differences between Silicon Carbide and Gallium Nitride Transistors in terms of gate drive design? Explain

5. Explain the design of IGBT driver circuit with over current protection.

PART B
Answer any 5 questions

6. (a) Draw the reverse recovery characteristics of a power diode and explain the terms (i) Reverse recovery time (ii) Peak inverse current and (iii) S-Factor. Also derive the expressions for reverse recovery time and peak inverse current. (7 marks)

7. Explain the EMI phenomenon in power electronic drives and discuss the various methods to reduce it. (7 marks)

(a) Explain the switching characteristics of P channel MOSFET (4 marks)

(b) Calculate the total power loss for the MOSFET having the following parameters:
8. V_{DS} = 120V, I_D = 4A, t_r = 80ns, t_f = 120ns, I_{DSS} = 2mA, $R_{DS(on)}$ = 0.2Ω, duty cycle D=50%, and $f_{switching}$ = 45kHZ. (3 marks)

9. Explain the constructional features, characteristics and gate drive requirements of IGCT (7 marks)

10. Explain the static and switching characteristics of GaN switching devices. (7 marks)

11. Explain the snubber requirements in GTO (7 marks)

12. Design a gate drive circuit for Silicon carbide MOSFET and describe the design challenges to be considered. (7 marks)

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221EEE027	FIELD THEORY	PROGRAM ELECTIVE 1	3	0	0	3

Preamble: This course intends to provide in-depth knowledge of electromagnetic waves and a detailed analysis of different analytical methods.

Prerequisites: Nil

Course Outcomes: The COs shown are only indicative. For each course, there can be 4 to 6 COs.
After the completion of the course, the student will be able to

CO 1	Apply different analytical methods based on Maxwell's law to understand wave propagation in time-varying fields
CO 2	To impart knowledge on the concept of polarization and wave propagation in bounded media
CO 3	To develop analytical skills for applying Poynting vector in dielectrics and conductors
CO 4	To illustrate the concept of transverse electromagnetic waves
CO 5	To identify the characteristics of radio wave propagation and basic antenna parameters

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3						
CO 2			3				
CO 3				3	3		
CO 4			3				
CO 5	3	3					
CO 6							

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	40
Analyse	40
Evaluate	10
Create	10

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred)	:	15 marks
Course based task/Seminar/Data collection and interpretation	:	15 marks
Test paper, 1 no.	:	10 marks

Test paper shall include minimum 80% of the syllabus

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to heoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question paper
APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
THIRD SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2016

Electrical & Electronics Engineering

221EEE027: FIELD THEORY

Time: 2.5 hours Max marks: 60

Answer **any two full** questions from each part.

Part A (Answer all questions)

1	What do you meant by depth of polarization?	(5)
2	What is polarization? Explain elliptical polarization?	(5)
3	Briefly explain poynting theorem?	(5)
4	Distinguish between TE, TM, and TEM waves?	(5)
5	Explain electromagnetic wave spectrum ?	(5)

Part B (Answer any 5 questions)

6	Derive the wave equations in **E** and **H** for a conducting medium using Maxwell's equations for time varying fields.	(7)
7	Derive an expression for E and H when a wave is incident normally on a perfect conductor?	(7)
8	Explain the flow of direct current in a cylindrical resistor using the concept of Poynting vector	(7)
9	Explain the different velocities of propagation of electromagnetic waves ?	(7)
10	Explain the following parameters a) Radiation patterns b) Radiation intensity c) Beam area d) Beam efficiency e) Directivity f) Power gain	(7)
11	Briefly describe the propagation of TEM waves in co-axial cables. Also show that TEM wave is the only possible wave in such cables.	(7)
12	Determine the i)phase velocity ii)propagation constant iii)attenuation constant iv) intrinsic impedance for a 1MHz plane wave in a large copper block with σ =5.8x10 7 S/m, ϵ_r =1 and μ_r =1	(7)

SYLLABUS

MODULE 1 (8Hrs)

Time-varying fields and electromagnetic waves: - Solution of Maxwell's equations for charge free unbounded region -Uniform waves - Uniform plane waves - Wave propagation in good dielectrics, conductors - Depth of penetration.

MODULE 2 (8Hrs)

Polarization: - Elliptic, Linear and Circular polarization. Waves at boundary between two media - Wave incident normally on boundary between perfect dielectrics -Wave polarized parallel to the plane of incidence- Brewster angle - Wave incident normally on perfect conductor.

MODULE 3 (8 Hrs)

Poynting Vector - Poynting Vector for a plane wave in a dielectric -Poynting theorem- Flow of direct current in cylindrical resistor – Flow of direct current in coaxial cables

MODULE 4 (8 Hrs)

Guided waves: - Essential conditions -Transverse electric (TE) waves - Transverse magnetic (TM)waves - Characteristics –Transverse Electro-Magnetic(TEM) waves-Velocities of Propagation - TEM waves in co-axial cables and two-wire transmission line - Attenuation factor for TE, TM and TEM waves.

MODULE 5 (8 Hrs)

Propagation characteristics of Radio waves:- Electro-magnetic wave spectrum – Transmission path from transmitter to receiver Antennas- Definition- Working principle- Types of antennas- Basic antenna parameters- Radiation patterns- Radiation intensity- Beam area- Beam efficiency- Directivity- Power gain

Course Plan

(For 3 credit courses, the content can be for 40 hrs and for 2 credit courses, the content can be for 26 hrs. The audit course in third semester can have content for 30 hours).

No	Topic	No. of Lectures
1	**Time-varying fields and electromagnetic waves (8 Hrs)**	
1.1	Solution of Maxwell's equations for charge free unbounded region	1
1.2	Uniform waves	1
1.3	Uniform plane waves	1
	Characteristics of wave impedance and propagation	2
1.4	- Wave propagation in good dielectrics	1
1.5	Wave propagation in good conductors and Depth of penetration	2
2	**Polarization (8 Hrs)**	
2.1	Polarization - Elliptic, Linear and Circular polarization.	2
2.2	Wave incident normally on boundary between perfect dielectrics -	2
2.3	Wave polarized parallel to the plane of incidence- Brewster angle	2
2.4	Wave incident normally on perfect conductor	2
3	**Poynting Vector (8 Hrs)**	
3.1	- Poynting Vector for a plane wave in a dielectric	2
3.2	Flow of direct current in cylindrical resistor	3
3.3	Flow of direct current in coaxial cables	3
4	**Guided waves - -Transverse electric (TE) waves (8 Hrs)**	
4.1	Essential conditions	1
4.2	- Transverse magnetic (TM)waves - Characteristics –Transverse Electro Magnetic(TEM) waves-	1
4.3	Velocities of Propagation	2
4.4	TEM waves in co-axial cables	1
4.5	TEM waves in two wire transmission line	1
	Attenuation factor for TE, TM and TEM waves	2
5	**Antenna and Propagation characteristics of Radio waves - (8 Hrs)**	
5.1	Electro-magnetic wave spectrum	2
5.2	Transmission path from transmitter to receiver	2
5.3	Antennas- Definition- Working principle- Types of antennas	2
5.4	Basic antenna parameters- Radiation patterns- Radiation intensity- Beam area- Beam efficiency- Directivity- Power gain	2

Reference Books

1. Matthew N.O. Sadiku, Principles of Electromagnetics, Oxford University Press, 6th Edition.
2. Hayt W. H. and J. A. Buck, Engineering Electromagnetics, McGraw-Hill, 8th Edition.
3. K D Prasad, Antenna and wave propagation

CODE 221EEE028	WIND ENERGY CONVERSION SYSTEMS	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 1	3	0	0	3

Preamble: This course aims to provide knowledge on the construction, operation, and control of various parts in wind energy power generation unit.

Prerequisites: Nil

Course Outcomes: The COs shown are only indicative. For each course, there can be 4 to 6 COs.
After the completion of the course the student will be able to

CO 1	Understand the technology of wind energy conversion system.
CO 2	Study the control methods in wind turbine.
CO 3	Understand the concepts of fixed speed and variable speed wind energy conversion systems.
CO 4	Study the power electronic converters in wind energy conversion system.
CO 5	Analyze the grid integration issues and mitigation techniques.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3	3					
CO 2			3	3			
CO 3				3	3		
CO 4						3	
CO 5						3	

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	40%
Analyse	30%
Evaluate	10%
Create	20%

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:
Preparing a review article based on peer reviewed
Original publications (minimum 10 publications shall be referred): 15 marks
Course based task/Seminar/Data collection and interpretation: 15 marks
Test paper 1 no.: 10 marks
Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:
End Semester Examination: 60 marks
The end semester examination will be conducted by the respective College.
There will be two parts; Part A and Part B.
Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question. Students should answer all questions.
Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions

relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question paper
APJ Abdul Kalam Technological University
M Tech Degree Examination
Model Question Paper
221EEE028 - WIND ENERGY CONVERSION SYSTEMS

Max. Marks: 60 Duration: 2.5 hours

Part A (Answer all questions)

1. Write short notes on (i) Power Coefficient, (ii) Beltz limit of wind turbine. [5]
2. Explain Torque – speed characteristics and Power – speed characteristics of wind turbine. [5]
3. Explain the choice of Generators for fixed speed wind energy conversion systems (WECS). [5]
4. Write short notes on Doubly fed induction generator in variable speed systems. [5]
5. With the help of block diagram explain standalone wind energy conversion system. [5]

Part B (Answer any 5 questions)

6. Explain strip theory in connection with the design of wind turbine.[7]
7. Define Tip speed ratio. Describe how the number of blades are selected in wind turbines. [7]
8. Derive the model of synchronous generator for WECS. [7]
9. Explain variable speed and variable frequency schemes of WECS with necessary diagrams. [7]
10. Explain the power control scheme of a grid tied wind energy conversion system. [7]
11. Explain any one MPPT technique for wind electrical systems. [7]
12. Explain Yaw control and pitch control in wind turbines. [7]

Syllabus and Course Plan (For 3 credit courses, the content can be for 40 hrs and for 2 credit courses, the content can be for 26 hrs. The audit course in third semester can have content for 30 hours).

Syllabus

Module 1

Basics of wind energy conversion: Components of WECS-WECS schemes, Power obtained from wind- Axial momentum theory – power coefficient – Betz limit, Blade element theory - Strip theory

Module 2

Classification of Wind Turbines - Vertical Axis Type, Horizontal Axis, Torque-Speed and Power-Speed Characteristics of Wind Turbines, Constant Speed Constant Frequency, Variable Speed Variable Frequency, Up Wind, Down Wind; Wind Turbine Control Systems: Pitch Angle Control, Stall Control, Yaw Control and Power Electronic Control, Control strategy.

Module 3

Generating Systems- Constant speed constant frequency systems -Choice of Generators - Deciding factors-Synchronous Generator-Squirrel Cage Induction Generator- Model of Wind Speed- Model wind turbine rotor - Drive Train model. Generator model for Steady state and Transient stability analysis

Module 4

Variable speed generators for WECS - Need of variable speed systems-Power-wind speed characteristics-Variable speed constant frequency systems synchronous generator- DFIG- PMSG - Variable speed generators modeling - Variable speed variable frequency schemes.

Module 5

Power Electronics Converters in Wind Application - Type of wind energy conversion system - Standalone system and Grid tied system, MPPT techniques for wind electrical systems (minimum 2 methods). Grid Tied Inverter, Power Management, Grid Monitoring Unit (Voltage and Current), Transformer, Power Control, Reactive Power Compensation.

Course Plan

No	Topic	No. of Lectures
1	Basics of wind energy conversion: Components of WECS-WECS schemes, Power obtained from wind- Axial momentum theory – power coefficient – Betz limit, Blade element theory - Strip theory	
1.1	Components of WECS-WECS schemes	2
1.2	Power obtained from wind- Axial momentum theory	2
1.3	Blade element theory - Strip theory	3
2	Classification of Wind Turbines - Vertical Axis Type, Horizontal Axis, Torque-Speed and Power-Speed Characteristics of Wind Turbines, Constant Speed Constant Frequency, Variable Speed Variable Frequency, Up Wind, Down Wind; Wind Turbine Control Systems: Pitch Angle Control, Stall Control, Yaw Control and Power Electronic Control, Control strategy	
2.1	Types of wind turbines - Vertical axis and horizontal axis type	2
2.2	Characteristics	2
2.3	Control methods	3
3	Generating Systems- Constant speed constant frequency systems - Choice of Generators - Deciding factors-Synchronous Generator- Squirrel Cage Induction Generator- Model of Wind Speed- Model wind turbine rotor - Drive Train model. Generator model for Steady state and Transient stability analysis	
3.1	Selection of generator	2
3.2	Synchronous generator and induction generator	2
3.3	Modeling of fixed speed WECS	3
3.4	Transient and steady state stability analysis	2
4	Variable speed generators for WECS - Need of variable speed systems- Power-wind speed characteristics-Variable speed constant frequency systems synchronous generator- DFIG- PMSG - Variable speed generators modeling - Variable speed variable frequency schemes.	
4.1	Need of variable speed generators	1
4.2	Variable speed constant frequency systems	1
4.3	PMSG and DFIG	2
4.4	Modeling of variable speed WECS	3
4.5	Variable speed variable frequency systems	1
5	Power Electronics Converters in Wind Application - Type of wind energy conversion system - Standalone system and Grid tied system, MPPT techniques for wind electrical systems (minimum 2 methods). Grid Tied Inverter, Power Management, Grid Monitoring Unit (Voltage and Current), Transformer, Power Control, Reactive Power Compensation.	
5.1	Types of wind energy conversion system – stand alone and grid connected	2
5.2	MPPT techniques for WECS	3
5.3	Grid integration – issues and mitigation methods	2
5.4	Active and reactive power control, Voltage control.	2

Reference Books

1. S. N. Bhadra, D. Kastha, S. Banerjee, Wind Electrical Systems, Oxford Univ. Press, New Delhi, 2005.
2. Wind energy Handbook, Edited by T. Burton, D. Sharpe, N. Jenkins and E. Bossanyi, John Wiley & Sons, 2001.
3. L .L. Freris, Wind Energy Conversion Systems, Prentice Hall, 1990.
4. Wind Power in Power Systems Edited by Thomas Ackermann 2005 John Wiley & Sons, Ltd.
4. Ion Boldea, "Variable speed generators", Taylor & Francis group, 2006
5. D. A. Spera, Wind Turbine Technology: Fundamental concepts of Wind Turbine Engineering, ASME Press.
6. Wind Energy: Fundamentals, Resource analysis and Economics, Mathew Sathyajith, 2006
7. S.Heir "Grid Integration of WECS", Wiley 1998.

CODE 221EEE030	MACHINE LEARNING	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 1	3	0	0	3

Preamble: This course enables the learners to understand the fundamental concepts in machine learning. The course covers the basic introduction, various estimation methods, most popular supervised and unsupervised learning algorithms. Course also throws light to neural network systems and classifier estimation process. This course will enable students to create machine learning based solutions to various real-world problems.

Prerequisites: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Illustrate machine learning concepts and basic parameter estimation methods along with central tendency measures. **(Cognitive Knowledge Level: Apply)**
CO 2	Describe the underlying mathematical relationships within and across Machine Learning algorithms and the paradigms of supervised learning. **(Cognitive Knowledge Level: Apply)**
CO 3	Illustrate the basic concepts of neural networks in-line with feed forward neural network and its training process along with machine learning classifiers **(Cognitive Knowledge Level: Apply)**
CO 4	Demonstrate and describe the underlying mathematical relationships within and across Machine Learning algorithms and the paradigms of unsupervised learning. **(Cognitive Knowledge Level: Apply)**
CO 5	Demonstrate and illustrate throw to compare various machine learning models along with the application of machine learning in control problems **(Cognitive Knowledge Level: Apply)**

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3		2	3	2		
CO 2	3		2	3	2		
CO 3	3		2	3	2		
CO 4	3		2	3	2		
CO 5	√	√					√

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	60 %
Analyse	20%
Evaluate	10%
Create	10%

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:
ELECTIVE COURSES Evaluation shall only be based on application, analysis or design-based questions (for both internal and end semester examinations).

Continuous Internal Evaluation: 40 marks
Preparing a review article based on peer reviewed original publications (minimum 10 Publications shall be referred) : 15 marks
Course based task/Project/Seminar/Data Collection and interpretation: 15 marks
Test paper,1 no.: 10 marks
Test paper shall include minimum 80% of the syllabus

End Semester Examination Pattern:
The end semester examination will be conducted by the respective College.
There will be two parts; Part A and Part B.
Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.
Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Model Question paper

QP CODE: PAGES:

Reg No:________________ Name:__________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

____SEMESTER_____DEGREE EXAMINATION, MONTH & YEAR

221EEE030 MACHINE LEARNING

Max.Marks:100 **Duration: 2.5 Hrs**

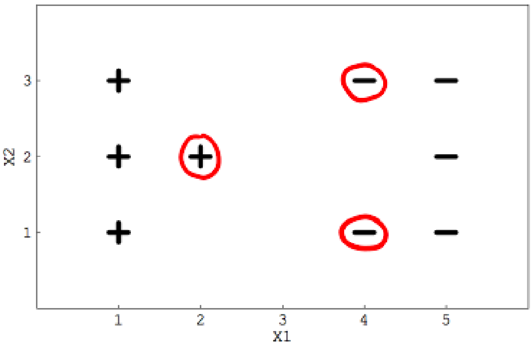
PART A

Answer all Questions. Each question carries 5 Marks

1.Explain how a system can play a game of Chess using reinforcement learning.

2. Suppose you have a dataset with m = 1000000 examples and n = 200000 features for each example. You want to use multivariate linear regression to fit the parameters to our data. Should you prefer gradient descent or the normal equation? Justify your answer.

3. Suppose you are using a Linear SVM classifier with 2 class classification problem and you are given the following data in which some points are circled red that are representing support vectors.



If you remove any one red points from the data. Does the decision boundary will change? Discuss in detail.

4. How can a generative model p(x|y) be used as a classifier? Also explain, why is dimensionality reduction useful?

5. A classifier has a high precision but low recall. What does this mean?

(5x5=25)

PART B

Answer any FIVE Question. Each question carries 7 Marks

6. Define supervised learning? Name and explain with suitable examples, the special cases of supervised learning depending on whether the inputs/outputs are categorical, or continuous.

7. How can you interpret the output of a two-class logistic regression classifier as a probability? Also, In a two-class logistic regression model, the weight vector w = [4, 3, 2, 1, 0]. We apply it to some object that we would like to classify; the vectorized feature representation of this object is x = [−2, 0,−3, 0.5, 3]. What is the probability, according to the model, that this instance belongs to the positive class? Discuss.

8. Consider a support vector machine whose input space is 2-D, and the inner products are computed by means of the kernel K(x, y) = (x.y + 1)2-1, where x.y denotes the ordinary inner product. Show that the mapping to feature space that is implicitly defined by this kernel is the mapping to 5-D given by

$$\mathbf{x} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \rightarrow \phi(\mathbf{x}) = \begin{bmatrix} x_1^2 \\ x_2^2 \\ \sqrt{2}\, x_1 x_2 \\ \sqrt{2}\, x_1 \\ \sqrt{2}\, x_2 \end{bmatrix}$$

.

a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*
(2,0)	(1,2)	(2,2)	(3,2)	(2,3)	(3,3)	(2,4)	(3,4)	(4,4)	(3,5)

Suppose that we have the following data:
Identify the cluster by applying the k-means algorithm, with k = 2. Try using initial cluster centers as far apart as possible.

10. Explain the various types of regression. Also, suppose if you are asked to perform linear regression to learn the function that outputs y, given the D-dimensional input x. You are given N independent data points, and that all the D attributes are linearly independent. Assuming that D is around 100, would you prefer the closed form solution or gradient descent to estimate the regressor?

11. Consider the two dimensional patterns (2, 1), (3, 5), (4, 3), (5, 6), (6, 7), (7, 8).
Compute the principal component using PCA Algorithm.

12. (a) Define Precision, Recall, Accuracy and F-measure?
(b)Fill in the missing values in the accompanying three class confusion matrix. Given that model accuracy is 72% and classification error for class 2 is 20%. Find also the precision and recall for class1.

		Predicted		
		Class 1	Class 2	Class 3
Actual	Class 1	14	2	5
	Class 2	? (x)	40	2
	Class 3	1	?(y)	18

(5x7=35)

Syllabus

Module I -Introduction

Introduction to Machine Learning - How do machines learn - Selecting the right features, understanding data: - numeric variables – mean, median, mode, Measuring spread.

Review of distributions: Uniform and normal. Categorical variables.

Machine learning paradigms-supervised, semi-supervised, unsupervised, reinforcement learning.

Module II -Supervised Learning

Supervised Learning - Regression - Linear regression with one variable, Linear regression with multiple variables, solution using gradient descent algorithm and matrix method, basic idea of overfitting in regression.

Linear Methods for Classification- Logistic regression, Perceptron, Naive Bayes, Classification using Decision Trees and Rules - Decision Tree algorithm ID3

Module-III - Neural Networks (NN) and Support Vector Machines (SVM)

NN - Multilayer feed forward network, Activation functions (Sigmoid, ReLU, Tanh), Back propagation algorithm.

SVM - Introduction, Maximum Margin Classification, Mathematics behind Maximum Margin Classification, Maximum Margin linear separators, soft margin SVM classifier, non-linear SVM, Kernels for learning non-linear functions, polynomial kernel, Radial Basis Function (RBF).

Module-IV -Unsupervised Learning

Clustering - Similarity measures, Hierarchical Agglomerative Clustering, K-means partitional clustering, Expectation maximization (EM) for soft clustering. Dimensionality reduction – Principal Component Analysis, factor Analysis,

Multidimensional scaling, Linear Discriminant Analysis.

Module-V - Classification Assessment and Appplications

Classification Performance measures - Precision, Recall, Accuracy, F-Measure, Receiver Operating Characteristic Curve(ROC), Area Under Curve(AUC. Bootstrapping, Cross Validation, Ensemble methods, Bias-Variance decomposition.

Applications to Control Problems: State estimation using neuro observer (single layer and multi layer), kalman filter and reinforcement learning, Identification of non-linear dynamical systems using neural networks (state space models and input-output models)

Optimal control problems using support vector machines, regression methods, monte-carlo method, model predictive control and adaptive reinforcement learning

Course Project: Develop a classifier for face detection application or similar simple problems.

Course Plan

No	Topic	No. of Lectures
1	**Introduction to Machine Learning (6 hrs)**	
1.1	Introduction to Machine Learning - How do machines learn -Selecting the right features.	1
1.2	Understanding data: - numeric variables – mean, median, mode, Measuring spread	1
1.3	Review of distributions: Uniform and normal. Categorical variables.	1
1.4	Machine learning paradigms-supervised, semi-supervised, unsupervised, reinforcement learning.	1
1.5	Machine learning paradigms-supervised, semi-supervised, unsupervised, reinforcement learning.	2
2	**Supervised Learning (10 hrs)**	
2.1	Supervised Learning - Regression - Linear regression with one variable, Linear regression with multiple variables.	2
2.2	Solution using gradient descent algorithm and matrix method, basic idea of overfitting in regression	3
2.3	Linear Methods for Classification- Logistic regression, Perceptron,	2
2.4	Naive Bayes, Classification using Decision Trees and Rules - Decision Tree algorithm ID3	3
3	**Neural Networks (NN) and Support Vector Machines (SVM)(8 hrs)**	
3.1	NN - Multilayer feed forward network, Activation functions (Sigmoid, ReLU, Tanh)	2
3.2	Back propagation algorithm.	2
3.3	SVM - Introduction, Maximum Margin Classification, Mathematics behind Maximum Margin Classification, Maximum Margin linear separators, soft margin	2
3.4	SVM classifier, non-linear SVM, Kernels for learning non-linear functions, polynomial kernel, Radial Basis Function (RBF).	2
4	**Unsupervised Learning (8 hrs)**	
4.1	Clustering - Similarity measures, Hierarchical Agglomerative Clustering.	2
4.2	K-means partitional clustering, Expectation maximization (EM) for soft clustering.	2
4.3	Dimensionality reduction – Principal Component Analysis,	2

	factor Analysis,	
4.4	Multidimensional scaling, Linear Discriminant Analysis	2
5	**Classification Assessment and Appplications (8 hrs)**	
5.1	Classification Performance measures - Precision, Recall, Accuracy, F-Measure, Receiver Operating Characteristic Curve(ROC), Area Under Curve(AUC. Bootstrapping, Cross Validation, Ensemble methods, Bias-Variance decomposition.	3
5.2	Applications to Control Problems: State estimation using neuro observer (single layer and multi-layer), kalman filter and reinforcement learning,; Identification of non-linear dynamical systems using neural networks (state space models and input-output models)	3
5.3	Optimal control problems using support vector machines, regression methods, monte-carlo method, model predictive control and adaptive reinforcement learning	2

Reference Books

1. Frank Leroy Lewis, Suresh Jagannathan, A. Yeşildirek, Neural Network Control of Robot Manipulators and Non-Linear Systems, Taylor and Francis group, 1999.
2. Frank L. Lewis, Derong Liu, Reinforcement Learning and Approximate Dynamic Programming for Feedback Control, Wiley and IEEE press, 2013
3. Zi-Xing Cai, Intelligent Control: Principles, Techniques and Applications World Scientific, 1997.
4. Bishop, C. M., Pattern Recognition and Machine Learning, Springer, 2006.
5. Alexander S. Poznyak, Edgar N. Sanchez, Wen Yu, Differential Neural Networks for Robust Nonlinear Control Identification, State Estimation and Trajectory tracking, World Scientific, 2001.
6. Alex Smola, S.V.N. Vishwanathan, Introduction to Machine Learning, Cambridge University Press, 2010.
7. Simon Haykins, Neural Networks and Learning Machines, Prentice Hall, 2009.
8. Related Research Articles from Journals and Conferences.

CODE 221EEE031	COURSE NAME OPERATION AND CONTROL OF GENERATORS	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 1	3	0	0	3

Preamble: This course aims to provide an overview of the different types of generators and to provide knowledge on operation and control of Synchronous generators in detail.

Prerequisites: Nil

Course Outcomes:
After the completion of the course the student will be able to

CO 1	Identify different types of electric generators and prime movers.
CO 2	Develop the model of synchronous generator and excitation systems.
CO 3	Explain the basics of speed governor and AGC.
CO 4	Apply reactive power control and voltage control in synchronous generators.
CO 5	Analyse wound rotor induction generators, self-excited induction generators and permanent magnet synchronous generators.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	2		3	3			
CO 2	2						
CO 3	2						
CO 4	2						
CO 5	2						

Assessment Pattern

Bloom's Category	End Semester Examination (%)
Apply	30
Analyse	50
Evaluate	20
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:
Continuous Internal Evaluation: 40 marks
Preparing a review article based on peer reviewed original publications (minimum 10 Publications shall be referred) : 15 marks
Course based task/Project/Seminar/Data Collection and interpretation: 15 marks
Test paper,1 no.: 10 marks
Test paper shall include minimum 80% of the syllabus

End Semester Examination Pattern:
There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question. Part B will contain 7 questions with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question paper

QP CODE:
Reg. No: _______________
Name : ________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
FIRST SEMESTER M. TECH DEGREE EXAMINATION,
MONTH & YEAR

Course Code: 221EEE031

Course Name: Operation and Control of Generators

Max. Marks: 60 Duration: 2.5

Part A

1.(a) With a neat diagram, explain the constructional details of any one types of Synchronous Generators and suggest suitable turbine for them. (5)

2. Model a separately excited DC generator as an exciter for synchronous generator (5)

3. Define AGC. With the block diagram, Explain Automatic generation control in an isolated power System (5)

4. Explain the production and absorption of reactive power in synchronous machine (5)

5. Draw and explain the phasor diagram of a WRIG for positive slip at rotor unity power factor (5)

Part B

6.Develop the model of steam turbine. (7)

7. Draw the block diagram of IEEE type AC1A excitation system and explain each block. (7)

8. Draw the schematic of an isochronous governor. Obtain the load sharing and time response of a generating unit with a governor having speed -droop characteristics (7)

9. What is a Self-Excited Induction Generator. Draw the equivalent circuit of a SEIG and explain its steady state performance (7)

10. Develop the d-q equivalent circuit and draw the general vector diagram of PMSG in generating mode (7)

11. With neat sketches explain the configuration and characterization of Permanent Magnet Synchronous Generator (7)

12. With block diagram, explain the working of DC Exciter, AC Exciter and Static Exciter applicable to synchronous generator (7)

Syllabus

MODULE 1

Electric Generators: Types of electric generators: Synchronous Generators-Permanent magnet synchronous generators, homopolar synchronous generators. Induction generator: Wound rotor doubly fed Induction generator. Parametric Generators: flux reversal generators, Transverse flux reversal generators, and linear motion alternators. Basic principle of working and construction, applications-

Prime movers- Hydraulic turbines -Basics, ideal model, speed governors. Steam turbines-modelling and speed governors of a steam turbine. Wind and gas turbines- basics only. (7hours)

MODULE 2

Excitation system-Brushless Excitation, Exciters-DC, AC, and static exciters. Exciter's modeling, -New PU system, DC exciter, AC exciter and static exciter. **Compensation of excitation systems**- Instability problem of exciter, solution to the instability of exciter, need of the power system stabilizer (PSS).**SG operation at Power Grid**-Power/angle characteristics, V-curves, reactive power capability curves, Defining static and dynamic stability of SGs. Phase to phase short circuit **SG: Modeling for Transients- d-q model, equivalent circuits. Mechanical transients-**response to shaft torque input, forced oscillation. (8hours)

MODULE 3

Control of Synchronous Generators: General control system, Speed Governing basics-SG with its own load, Isochronous speed governor, The primitive speed -droop governor, load sharing between two SGs with speed- droop governor, speed-droop speed governor with load reference control. Time response of speed governors. Automatic generation control-AGC control of one SG in a two SGs isolated power system, AGC as a multilevel control system. Control of generating unit power output (7hours)

MODULE 4

Reactive power and voltage control- Production and absorption of reactive power. Methods of voltage control: shunt reactors, shunt capacitors, series capacitors, synchronous condensers, static var systems. Automatic voltage regulation concept. Self-excited induction generators: cage rotor induction machine principle. Self-excitation -A qualitative view. Steady state performance of three phase SEIGs, Unbalanced operation of three phase SEIGs. (8 hours)

MODULE 5

Wound rotor induction generators-construction elements, steady state equations, equivalent circuit, phasor diagrams. Operation at the grid-stator power versus power angle, rotor power versus power angle and operation at zero slip. Autonomous operation of WRIGs, losses and efficiency, Direct power control of WRIG at grid. Permanent magnet synchronous generator systems.: Practical configuration and their characterization-distributed versus concentrated wings. Airgap field distribution, e.m.f and torque. Circuit model-phase coordinate model and d-q model (10 hours)

Course Plan (For 3 credit courses, the content can be for 40 hrs and for 2 credit courses, the content can be for 26 hrs. The audit course in third semester can have content for 30 hours).

No	Topic	No. of Lectures
1	**Electric Generators**:	
1.1	Synchronous generators-Permanent magnet synchronous generators, homopolar synchronous generators. Induction generator: Wound rotor doubly fed Induction generator. Parametric Generators: flux reversal generators, Transverse flux reversal generators, and linear motion alternators. Basic principle of working and construction applications.	4
1.2	**Prime movers**- Hydraulic turbines -Basics, ideal model, speed governors. Steam turbines-modelling and speed governors of steam turbine. Wind and gas turbines- basics only.	3
2	**Excitation system**	
2.1	Brushless Excitation, Exciters-DC, AC and static exciters. Exciter's modelling, -New pu system, DC exciter, AC exciter and static exciter.	2
2.2	**Compensation of excitation systems**- Instability problem of exciter, solution to the instability of exciter, need of the power system stabilizer (PSS).**SG operation at Power Grid**-Power/angle characteristics, V-curves, static and dynamic stability of SGs.	4
2.3	**SG: Modeling for Transients- d-q model, equivalent circuits. Mechanical transients.**	2
3	**Control of Synchronous Generators**:	
3.1	General control system, Speed Governing basics-SG with its own load, Isochronous speed governor.	2
3.2	Load sharing between two SGs with speed- droop governor, speed-droop speed governor with load reference control. Time response of speed governors.	3
3.3	Automatic generation control-AGC control of one SG in a two SGs isolated power system, Control of generating unit power output.	2
4	**Reactive power and voltage control**	
4.1	Production and absorption of reactive power. Methods of voltage control: shunt reactors, shunt capacitors, series capacitors, synchronous condensers, static var systems	3
4.2	Automatic voltage regulation concept. Self-excited induction generators: cage rotor induction machine principle	3
4.3	Steady state performance of three phase SEIGs, Unbalanced operation of three phase SEIGs	2

5	**Wound rotor induction generators**	
5.1	**Wound rotor induction generators**-construction elements, steady state equations, equivalent circuit, phasor diagrams. Operation at the grid-stator power versus power angle, rotor power versus power angle and operation at zero slip.	4
5.2	Autonomous operation of WRIGs, losses and efficiency, Direct power control of WRIG at grid.	2
5.3	Permanent magnet synchronous generator systems. Practical configuration and their characterization-distributed versus concentrated windings. Airgap field distribution, e.m.f and torque. Circuit model-phase coordinate model and d-q model	4

Reference Books

1. 1. P. Kundur, ‘Power system stability and control’ McGraw-Hill, 1994
2. Ion Boldea ,’Synchronous generators ‘ second edition,CRC Press ,2016
3. Ion Boldea,’Variable speed generator’ second edition,CRC Press,2016
4. P.S.Bhimbra, ‘Generalized theory of electrical machines ‘, Khanna Publishers, 2002
5. Hadi Saddat, ‘Power System Analysis’, McGraw-Hill, 2002
6. C. Concordia, ‘Synchronous Machines
7. W.D Stevenson, ‘Elements of Power system analysis’, 1995
8. A.E Fitzgerald and Kingsley. ‘Electric Machinery’, Fifth edition, McGraw-Hill, 1990

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221EEE032	FINITE ELEMENT METHODS FOR ELECTRICAL MACHINES	PROGRAM ELECTIVE 2	3	0	0	3

Preamble: This course aims to provide depth knowledge on the Finite Element Method and Magnetic analysis of Electrical Machine using FEA.

Prerequisites: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Understand the basic principle and procedures of Finite Element Analysis.
CO 2	Apply the Finite Element method to anlyse performance of different electrical machines.
CO 3	Study different processes involved in FEA.
CO 4	Evaluate Maxwell's equations using FEA
CO 5	Analyze Electrical and Magnetic field problems using FEA
CO 6	Develop Electrical machine virtually using FEM software

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	2		3	3	3		
CO 2	2		3	3	3		
CO 3			3	3	3		
CO 4	2		3	3	3		
CO 5	2		3	3	3		
CO 6	2		3	3	3		

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	50
Analyse	50
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred)	:	15 marks
Course based task/Seminar/Data collection and interpretation	:	15 marks
Test paper, 1 no.	:	10 marks

Test paper shall include minimum 80% of the syllabus

End Semester Examination Pattern:

There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question. Part B will contain 7 questions with a minimum of one question from each module of which students should answer any five. Each question can carry 7 marks.

Model Question paper

No. of Pages: 2 **SLOT: D**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Branch: **Electrical and Electronics**

Stream(s): **Electrical Machines**

221EEE032- FINITE ELEMENT METHODS FOR ELECTRICAL MACHINES

Max. Marks: 60 Duration: 2.5 hours

PART A

(Answer all questions. Each question carries 5 marks)

1. Explain the major errors in FEA
2. Describe the process of discretization.
3. Derive Maxwells equations for static magnetic field
4. Explain different boundary conditions applicable to electrical machines**.**
5. What are the effects of saturation of iron core in the performance of electrical machines?

PART B

(Answer any 5 questions. Each carry 7 marks)

6. Explain different applications of FEA in electrical engineering.
7. State the two-dimensional field problem and account the steps to solve the problem applying variational method.
8. Compute no-load characteristics of synchronous generator using FEA.
9. Derive the mechanical torque of PMSM flux linkage and current method using FEA.
10. Discuss the no-load simulation of three phase induction motor.
11. Explain the importance of flux plots in the analysis of electrical machines.
12. Explain how the inductances and leakage inductance of a single-phase transformer are calculated using FEA

SYLLABUS

MODULE 1

Introduction to Finite Element Method: History and evolution of FEA, Application of FEA with examples – Automotive, Electrical, and Electronics Engineering, Aerospace.
Basic Principle of Finite Element Methods-general steps of finite element methods -Typical finite elements -discretization

MODULE 2

Field problems with boundary conditions-Classical method for the field problem solution - Classical Residual method (Garlekin's method) -Classical variational method (Rayleigh- Ritz's method)- The finite Element Method -Partition of the Domain (discretization)- Choice of the Interpolating Function- Formulation of the System- Application of the finite element method to two dimensional fields -two dimensional field problem-linear interpolation of the function φ-description of electromagnetic field

MODULE 3

The procedure for Finite Element Analysis- Boundary conditions-Dirichlet's condition-Neumann's condition-Periodic condition. Computation of solved structure -Magnetic Flux Linkage -Joule Power Losses-Magnetic Energy-Magnetic Co-energy-Magnetic Forces-Determination of Electrical Parameters. Finite Element Analysis of low power single phase transformer- method of finite element formulation. Equivalent circuit. Computation of the no-load inductances Computation of leakage inductance.Flux pot- Effect of nonlinear B-H curve-estimation of iron losses. Computation with linear and non-linear core. effect of the air gap.

MODULE 4

Finite Element Analysis of Synchronous generators. Structure of synchronous generator. Computation of no-load characteristics. Computation of direct axis and quadrature axis inductance. Computation of self and mutual inductances. Effect of saturation. Computation of Ld and Lq with any current. Computation of machine characteristics. Analysis of flux plot and flux density distribution. Finite Element Analysis of PMSM: Computation of no-load characteristics -computation on the solved structure -flux linkage, induced emf. computation of various rotor positions -flux linkage and induced emf, cogging torque, Computation of inductances. computation of torque by means of flux linkage and currents.

MODULE 5

Finite element analysis of three phase induction motor-Construction of the equivalent circuit -No-load and block rotor test simulations, Motor analysis using simulations under load-Magnetic field equations under load, non-linearity of the magnetic materials, computation of mechanical torque-Examples, Familiarisation of any one software of finite element method. analysis of field problems using software, Modelling and analysis of cage rotor using software

Course Plan

(For 3 credit courses, the content can be for 40 hrs, and for 2 credit courses, the content can be for 26 hrs. The audit course in the third semester can have content for 30 hours).

No	**Topic**	No. of Lectures
1	**Introduction to Finite Element Method:**	
1.1	Scope of FEA in electrical machines. Limitations of conventional design-	2
1.2	Merits and demerits of FEA in the design of electrical machines and equipment.	2
1.3	Basics of electromagnetics Maxwells equations for Steady electric field, steady magnetic field and time-varying electromagnetic field.	2
2	**Field problems with boundary conditions**	
2.1	Field problems with boundary conditions-Classical method for the field problem solution - Classical Residual method (Garlekin's method) -Classical variational method (Rayleigh-Ritz's method)	3
2.2	The finite Element Method -Partition of the Domain (discretization)- Choice of the Interpolating Function-Formulation of the System.	3
2.3	Application of the finite element method to two dimensional fields -two-dimensional field problem-linear interpolation of the function φ-description of electromagnetic field	3
3	**Procedure for Finite Element Analysis-**	
3.1	Computation of solved structure -Magnetic Flux Linkage - Joule Power Losses-Magnetic Energy-Magnetic Co-energy-Magnetic Forces-Determination of Electrical Parameters.	3
3.2	Finite Element Analysis of low power single phase transformer- method of finite element formulation. Equivalent circuit . . Computation of the no-load inductances Computation of leakage inductance.Flux pot	3
3.3	Effect of nonlinear B-H curve-estimation of iron losses. Computation with linear and non-linear core. effect of air gap. .	3
4	**Finite Element Analysis of Synchronous generators.**	
4.1	Effect of saturation. Computation of Ld and Lq with any current. Computation of machine characteristics. Analysis of flux plot and flux density distribution	3
4.2	Finite Element Analysis of PMSM: Computation of no-load characteristics -computation on the solved structure -flux linkage, induced emf. computation of various rotor positions -flux linkage and induced emf, cogging torque.	3
4.3	Computation of inductances. computation of torque by means of flux linkage and currents.	2
5	**Finite element analysis of three phase induction motor**	
5.1	Motor analysis using simulations under load-Magnetic field equations under load, non-linearity of the magnetic materials, computation of mechanical torque. Example	3
5.2	Familiarisation of any one software of finite element method. analysis of field problems using software	3

5.3	Modelling and analysis of cage rotor using soft ware	2

Reference Books

1. "Text book of Finite Element Analysis ", P Seshu, PHI Learning Private Limited.
2. "Electrical Machines analysis using Finite Elements", Nicola Bianchi, CRC , Taylor and Francis .

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221EEE007	EMBEDDED CONTROLLERS FOR POWER CONVERTERS	PROGRAM ELECTIVE 2	3	0	0	3

Preamble: The course provides a solid foundation for the PIC18F4580 controller and it is used to develop embedded systems for various power converter circuits. Additionally, the course gives an overview of advanced DSP controllers and FPGA-based systems.

Prerequisites: Nil

Course Outcomes:
After the completion of the course the student will be able to

CO 1	Design embedded systems using PIC18F4580 controller
CO 2	Design and develop various power converter circuits using embedded system
CO 3	Use of any high performance C28X microcontrollers such as F28069/280049 /28335/28379 for converter control
CO 4	FPGA based system design using VHDL for converter control

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3	-	1	2	3	1	-
CO 2	3	-	1	2	3	1	-
CO 3	3	-	1	2	3	1	-
CO 4	3	-	1	2	3	1	-

Assessment Pattern

Bloom's Category	Continuous Assessment Tests	End Semester Examination
	1	
Remember		
Understand		10
Apply	20	40
Analyse	40	40
Evaluate	20	10
Create	20	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:
Continuous Internal Evaluation: 40 marks

- Preparing a review article based on peer reviewed Original publications (minimum 10 publications shall be referred): 15 marks
- Course based task/Seminar/Data collection and interpretation: 15 marks
- Test paper, 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1

question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension,
application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example, if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Model Question paper

QP CODE: **PAGES:**

Reg No:_______________

Name:___

____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 221EEE007

Course name: EMBEDDED CONTROLLERS FOR POWER CONVERTERS

Max Marks: 60

Duration: 2.5 Hours

PART-A (Answer All Questions. Each question carries 5 marks)

1) Write a program to get the x value from port A and send (x2+2x+3) to port B. Assume that RA0-RA7 has the x value of 0 – 9.

2) Write an assembly language or C program to measure the frequency of a pulse, XTAL = 20MHz.

3) Control a DC-to-DC converter using PIC18F4580 with switching frequency = 8 kHz, duty cycle = 55%. Use port C as output port and XTAL = 16MHz.

4) Write a program to implement the PI controller using PIC 18F?

5) Describe the PWM module of C28X microcontroller

PART-B (Answer any 5 Questions. Each question carries 7 marks)

6) Describe the PWM module of PIC 18F and explain how a 10KHz, 25% duty cycle PWM can be generated. The crystal frequency is 20MHz

7) Design a microcontroller-based voltage measurement system with LCD display

8) Draw the flowchart and write a program to measure the power factor of an RL load using PIC 18F4580.

9) Write a program to generate the firing pulses for a single-phase full-converter with firing angle of 45^0 using PIC 18F microcontroller.

10) In a boost converter based solar PV system, the PV panel voltage varies from 10V to 15V depending on the solar radiation. Design an MPPT based control system (PIC18F4580). Use the P & O algorithm for MPPT.

11) Describe the PWM module of C28X and explain how a 10KHz, 25% duty cycle PWM can be generated using embedded coder/C-program.

12) (a) Explain why FPGA is preferred in some applications when compared to

EE4

microcontrollers

13) (b) Write a VHDL code to insert a 1us delay for a pulse input at the rising edge. Explain how this could be used for deadtime generation

Syllabus

No	EMBEDDED CONTROLLERS FOR POWER CONVERTERS	Contact hours
1	**Microchip PIC 18F4580:** Architecture of PIC18F4580 microcontroller, PIC memory organization, Interrupt structure, Timers Counters, Capture, compare and PWM modules, Master Synchronous Serial Port (MSSP) module, A/D Converter module, Comparator module.	9
2	**Typical functions and Assembly/C-language programming of PIC18F4580 microcontrollers:** Measurement of voltage, current, power and power factor of RL load, speed, frequency measurement, ADC programming with polling and interrupt- PWM generation- Interfacing of LCD Display- familiarisation of programming tools	7
3	**Application and programming of PIC18F4580 microcontroller in power converters:** Zero Crossing Detectors- generation of gating signals for single and three phase-controlled rectifiers- Enhanced PWM- Half bridge and Full Bridge- Dead time generation- PWM generation for single phase square wave and sine wave inverters	7
4	**MODULE:4 - PIC18F4580 based system control:** Implementation of PI, PID controller- power factor correction using capacitor switching and boost front end converter- solar MPPT- P&O and incremental conductance - V/F control of single-phase induction motor- Interfacing of DAC converter- Miscellaneous examples	7
5	**MODULE: 5 - Introduction to high performance Microcontroller and FPGA based system design** C2000 microcontrollers- overview of architecture and peripherals of any selected C28X FPU microcontroller such as F28069/280049/28335/28379- GPIO, SCI, ADC, PWM and Encoder- Programming with C/Simulink embedded coder FPGA Based System Design- Introduction- VHDL programming- test bench- design of basic combinational, sequential and finite state machines- realization using any FPGA board (altera/xilinx/altium/efinix etc.) Case studies of power electronic converter control using any C28x microcontroller and/ FPGA board	10

Course Plan

No	Topic	No. of Lectures
1	**MODULE:1 - Microchip PIC 18F4580**	
1.1	Architecture of PIC18F4580 microcontroller, memory organization	2
1.2	Timer & counter programming	2
1.3	Capture, compare and PWM modules	2
1.4	A/D Converter module	1
1.5	Master Synchronous Serial Port (MSSP) module	1
1.6	Interrupt structure, Comparator module	1
2	**MODULE:2 - Typical functions and Assembly/C-language programming of PIC18F4580 microcontrollers:**	
2.1	Measurement of voltage, current, power	2
2.2	Measurement of Power factor of RL load	1
2.3	Measurement of speed, frequency	1
2.4	ADC programming with polling and interrupt, PWM generation	2
2.5	Interfacing of LCD Display	1
3	**MODULE:3 - Application and programming of PIC18F4580 microcontroller in power converters:**	
3.1	Zero Crossing Detectors- generation of gating signals for single and three phase-controlled rectifiers	3
3.2	Enhanced PWM- Half bridge and Full Bridge- Dead time generation	2
3.3	PWM generation for single phase square wave and sine wave inverters	2
4	**MODULE:4 – PIC18F4580 based system control:**	
4.1	Implementation of PI, PID controller	1
4.2	Power factor correction using capacitor switching and boost front end converter	2
4.3	Solar MPPT- P&O and incremental conductance	2
4.4	V/F control of single-phase induction motor- Interfacing of DAC converter	2
5	**MODULE:5 - Introduction to high performance Microcontroller and FPGA based system design**	
5.1	C2000 microcontrollers- overview of architecture and peripherals of any selected C28X FPU microcontroller such as F28069/280049/28335/28379	1
5.2	GPIO, SCI, ADC, PWM and Encoder	2
5.3	Programming with C/Simulink embedded coder	1
5.4	FPGA Based System Design- Introduction- VHDL programming	2
5.5	Test bench- design of basic combinational, sequential and finite state machines. Realization using any FPGA board (altera/xilinx/altium/efinix etc.)	2
5.6	Case studies of power electronic converter control using any C28x microcontroller and/FPGA board	2

Text Books:

1. Muhammad Ali Mazidi, Rolind D. Mckinlay, Danny Causey. “PIC microcontroller and Embedded Systems – using assembly and C for PIC18”, Pearson, 2013

2. Han Way Huang, “PIC Microcontroller, An introduction to software and hardware interfacing”, Delmar – 2007

3. Mattia Rossi, Nicola Toscani, Marco Mauri, Francesco Castelli Dezza, “Introduction to Microcontroller Programming for Power Electronics Control Applications_ Coding with MATLAB and Simulink”, CRC Press, 2022

4. V.A. Pedroni, “Circuit design with VHDL”, MIT Press, 2020

5. Bekkay Hajji, Adel Melli,Loubna Bouselham, “Practical Guide For Simulation and Fpga Implementation of Digital Design”, Springer, 2022

References:

1. Richard H. Barnett, Larry O'Cull, Sarah Alison Cox, Embedded C Programming and the Microchip PIC, Volume 1, Thomson Delmar Learning

2. Kenjo.T, "Power electronics for microprocessor Age", Clarendon press, Oxford, 1999

3. GourabSen Gupta, Subhas Chandra Mukhopadhyay, “Embedded Microcontroller Interfacing, Designing Integrated Projects”, Springer, 2010

4. H.A. Toliyat, S.Campbell, DSP based ElectroMechanical Motion Control, CRC Press-2004

5. PIC18F4580 Data Sheet – DS39637D, Microchip Technology Inc., 2009

221EEE029	SYSTEM THEORY	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 2	3	0	0	3

Preamble: The concepts in this course are considered advanced in the field of modern control theory. This course provides design of controllers, filters and stability analysis of nonlinear systems

Prerequisites: Nil

Course Outcomes: After the completion of the course, the student will be able to

CO 1	Design controllers and observers satisfying desired specifications
CO 2	Estimate the states of the system using Kalman filter
CO 3	Analyze the stability of the system using Lyapunov theorem
CO 4	Design sliding mode controllers for a system.
CO 5	Design adaptive controllers for a system

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3		2	3	3	2	
CO 2	3		2	3			
CO 3	3		2				
CO 4	3		2	3			
CO 5	3		2	3			

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	30
Analyse	50
Evaluate	20
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed Original publications (minimum 10 publications shall be referred) : 15 marks
Course based task/Seminar/Data collection and interpretation : 15 marks
Test paper, 1 no. : 10 marks
Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Model Question Paper

Pages **SLOT**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY FIRST SEMESTER M.TECH DEGREE EXAMINATION, MONTH & YEAR

221EEE029: SYSTEM THEORY

Max. Marks: 60 **Time: 2.5 hrs**

	Part A **(Answer all questions)**	**Marks**
1	A state equation of the system is given as $x' = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & -2 & -3 \end{bmatrix} x + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u$ $y = \begin{bmatrix} 3 & 4 & 1 \end{bmatrix} x$. Check whether the system is completely controllable and observable	(5)
2	Consider the task of estimating the states of a double integrator where noise with intensity 1 affects the input only and we have measurement noise of intensity 1. Determine the Kalman filter. What are the Kalman filter poles?	(5)
3	A nonlinear system described by the differential equation $y'' + y'(y^2 + (y')^2) + y = 0$. Check the stability of the system using Lyapunov stability criterion	(5)
4	In a sliding mode there exists a finite reaching time $t = t_f$ at which switching function s(t) becomes 0. Derive an expression for t_f in terms of s(0)	(5)
5	Design a MRAC for a first order system using MIT rule.	(5)
	Part B **(Answer any five questions)**	
6	Consider the system defined by $\dot{x} = Ax + bu$, where $A = \begin{bmatrix} -1 & 0 & 0 \\ 1 & -2 & 0 \\ 0 & 1 & -3 \end{bmatrix}$	(7)

	$b = \begin{bmatrix} 10 \\ 1 \\ 0 \end{bmatrix}$. Design a state feedback controller that places the eigen values at s = $-1 \pm j2$, -6.	
7	Design a controller observer transfer function of the plant $\frac{Y(s)}{U(s)} = \frac{1}{(s+3)(s+2)}$ to place the eigen values are at s = $-1 \pm$ j3 and the observer poles at s= -8, -8	(7)
8	A Kalman filter should be designed for the second-order system $\dot{x}(t) = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} x(t) + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u(t) + w_1(t)$; $y(t) = [1 \quad 0]x(t) + w_2(t)$ where w_1 and w_2 are uncorrelated white noise processes with intensities $R_1 = \begin{bmatrix} 3 & 0 \\ 0 & 3 \end{bmatrix}$ and $R_2 = 1$, respectively. Calculate the minimum observer error covariance P and the Kalman filter gain K. Also Write down the resulting filter equations for $\hat{x} nd \hat{x}$.	(7)
9	Construct a Lyapunov function for the given system using variable gradient method $x_1' = x_2, \quad x_2' = -x_1^3 - x_2$	(7)
10	Consider the system given by $x' = \begin{bmatrix} 0 & 1 \\ 4 & 5 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} (u + 0.5cost)$. Design a stable sliding surface for a given system	(7)
11	Obtain the equivalent control for a simple pendulum with a friction when torque is applied.	(7)
12	. a) Explain the design of Self Tuning Regulator by pole placement design. b) Explain the least square estimation for parameter estimation.	(7)

Syllabus

Module 1

State Variable Analysis and Observer design of Linear Systems (6 hrs):

Review of State variable representation of continuous time system- Controllable and observable and Jordan canonical form representation - Controllability and Observability- controller design using pole placement.

Observers: Asymptotic observers for state measurement. Implementation of full order and reduced order observers , separation principle, the combined observer-controller.

MATLAB experiments: state-space, controllability and observability, combined controller observer-design

Module 2

Filter Design (8 hours):

Sample Spaces and Events - Random-Variables. - Bayes' Formula- Expectation - Variance - Covariance - White and Colored Noises-Correlated Noise. Least Square Estimation-Weighted Least Square Estimation, Recursive Least Square Estimation.Wiener filtering - Propagation of States and Co-Variance - Kalman filter design. Extended Kalman filter design Introduction to Linear Quadratic Regulator (LQR) and Linear Quadratic Gaussian (LQG) techniques

Module 3

Nonlinear System Analysis (8 hours):

Nonlinear systems: Introduction, equilibrium/singular points, concept of stability. Stability: Lyapunov theory, asymptotic stability and instability, Lyapunov's direct and indirect methods. Lyapunov's stability analysis of LTI continuous-time systems. Construction of Lyapunov function using variable gradient method.

Module 4

Controller design (9 hours):

PID controllers: Effect of proportional, integral and derivative gains on system performance, PID tuning - Ziegler Nichols Methods, integral windup and solutions.

Introduction to Variable Structure Systems (VSS) - examples , Introduction to sliding mode control- - sliding surface- examples of dynamical systems with sliding modes, reaching laws-reachability condition, Invariance conditions- chattering-equivalent control, Design of sliding mode controllers using pole placement, LQR method.

Module 5

Adaptive Controllers (8 hours):

Adaptive Control, effects of process variation - Adaptive Schemes - Adaptive Control problem - Applications - RealTime Parameter Estimation: Introduction - Regression Models - Recursive Least Squares, Self Tuning Regulators introduction, pole placement design, Model Reference Adaptive systems (MRAS) - the need for MRAS , MIT rule, MRAS for first order system.

Course Plan

No	Topic	No. of Lectures
1	**State Variable Analysis and Observer design of Linear Systems (7 hrs):**	
1.1	Review of State variable representation of continuous time system	1
1.2	Controllable and observable and Jordan canonical form representation - Controllability and Observability	1
1.3	controller design using pole placement.	1
1.4	Observers: Asymptotic observers for state measurement. Implementation of full order observer	2
1.5	Implementation of reduced order observer, separation principle, the combined observer-controller.	2
2	**Filter Design (8 hours):**	
2.1	Sample Spaces and Events - Random-Variables. - Bayes' Formula- Expectation	1
2.2	Covariance - White and Colored Noises-Correlated Noise. Least Square Estimation-Weighted Least Square Estimation	2
2.3	Recursive Least Square Estimation.Wiener filtering - Propagation of States and Co-Variance - Kalman filter design	3
2.4	Extended Kalman filter design Introduction to Linear Quadratic Regulators (LQR) and Linear Quadratic Gaussian (LQG)	3
3	**Nonlinear System Analysis (8 hours):**	
3.1	Nonlinear systems: Introduction, equilibrium/singular points, concept of stability	1

3.2	Stability: Lyapunov theory, asymptotic stability and instability,	2
3.3	Lyapunov's direct and indirect methods. Lyapunov's stability analysis of LTI continuous-time systems.	2
3.4	Construction of Lyapunov function using variable gradient method	3
4	**Controller design (9 hours):**	
4.1	PID controllers: Effect of proportional, integral and derivative gains on system performance	1
4.2	PID tuning - Ziegler Nichols Methods, integral windup and solutions	1
4.3	Introduction to Variable Structure Systems (VSS)- examples , Introduction to sliding mode control- -sliding surface	2
4.4	Examples of dynamical systems with sliding modes , reachability condition, Invariance conditions- chattering-equivalent control	3
4.5	Design of sliding mode controllers using pole placement, LQR method	2
5	**Adaptive Controllers (8 hours):**	
5.1	Adaptive Control, effects of process variation - Adaptive Schemes - Adaptive Control problem - Applications	2
5.2	RealTime Parameter Estimation: Introduction - Regression Models - Recursive Least Squares,	2
5.3	Self Tuning Regulators introduction, pole placement design,	2
5.4	Model Reference Adaptive systems (MRAS) - the need for MRAS , MIT rule, MRAS for first order system.	2

Reference Books

1. M. Gopal, "Modern Control System Theory", Tata McGraw-Hill, 2nd Edition, 1993.
2. H. Khalil, "Nonlinear Control Systems", Prentice Hall Inc, New Jersey, 2002.
3. Katsuhiko Ogata, "Modern Control Engineering", Prentice-Hall of India, New Delhi, 2009.
4. J. Nagarath and M. Gopal, "Control system Engineering", New Age International (P) Ltd, 2007.
5. Katsuhiko Ogata, "State Space Analysis of Control Systems", Prentice Hall Inc, New Jersey, 1996.
6. Benjamin C. Kuo and Farid Golnaraghi, "Automatic Control Systems", 9th Edition, John Wiley & Sons, 2010.
7. Jean-Jacques E, Slotine, Weiping Li, "Applied Nonlinear Control", Prentice Hall Inc., New Jersey, 2005.
8. C Edwards and Sarah Spurgeon, " Sliding Mode Control: Theory And Applications", Taylor and Francis,1998
9. K. J. Astrom and B. Wittenmark, "Adaptive Control", 2nd Edition, Addison-Wesley, 1995
10.. S. Sastry and M. Bodson, "Adaptive Control", Prentice-Hall, 1989

221EEE008	POWER QUALITY, EMI ISSUES AND REMEDIAL TECHNIQUES	CATEGORY	L	T	P	CREDIT
		Program Elective 2	3	0	0	3

Preamble: The course attempts to impart knowledge about power quality issues, and mitigation techniques. It also covers the EMI issues, measurement and Electromagnetic compatibility (EMC) compliance in power electronics and electronic circuits. A basic course in power electronics is desirable as a prerequisite.

Course Outcomes: After the completion of the course the student will be able to

CO 1	Classify and Illustrate power quality issues
CO 2	Analyse power system harmonics and examine its effect on performance parameters
CO 3	Select suitable custom power devices and design using suitable control strategies like PQ theory
CO 4	Identify the EMI causes, measurement and mitigation methods
CO 5	Select suitable PCB layout and decoupling to reduce EMI

Mapping of course outcomes with program outcomes

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**
CO 1	2	1	3	2	2	2	
CO 2	2	1	3	2	2	2	
CO 3	2	1	3	2	2	2	
CO 4	2	1	3	2	2	2	
CO 5	2	1	3	2	2	2	

PO1: An ability to independently carry out research/investigation and development work in engineering and allied streams

PO2: An ability to communicate effectively, write and present technical reports on complex engineering activities by interacting with the engineering fraternity and with society at large.

PO3: An ability to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

PO4: An ability to apply stream knowledge to design or develop solutions for real world problems by following the standards

PO5: An ability to identify, select and apply appropriate techniques, resources and state-of-the-art tool to model, analyse and solve practical engineering problems.

PO6: An ability to engage in life-long learning for the design and development related to the stream related problems taking into consideration sustainability, societal, ethical and environmental aspects

PO7: An ability to develop cognitive load management skills related to project management and finance which focus on Entrepreneurship and Industry relevance.

Assessment Pattern

Bloom's Category	**End Semester Examination**
Apply	40%
Analyse	30%
Evaluate	20%
Create	10%

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: 40 marks
Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred) : 15 marks
Course based task/Seminar/Data collection and interpretation: 15 marks
Test paper, 1 no.: 10 marks
Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension,
application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.
Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example, if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Model Question paper

	Model Question paper	**Slot E**
APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY		
FIRST SEMESTER M. TECH DEGREE EXAMINATION MONTH & YEAR		
Course code: 221EEE008	Course Name: POWER QUALITY, EMI ISSUES AND REMEDIAL TECHNIQUES	
Max. Marks: 60		Duration: 2.5 Hours

	Part A (Answer all questions)	**5x5=25**
1	Explain the various types of transients and issues associated with them	5
2	Explain the harmonics in single phase-controlled converters	5
3	Explain the principle of shunt active filter for harmonic mitigation	5
4	Calculate the conducted noise emission through the capacitance of the heat sink in SMPS. Design a suitable filter to reduce this noise below the limit.	5
5	What are the advantages of using multilayer PCBs for digital circuits? Explain the mechanism of cross talk in multilayer PCBs and methods to reduce cross talk.	5
	Part B (Answer any five questions)	**7x5=35**
6	Explain the voltage magnification at load end due to capacitor switching, its effect on equipments and how it can be avoided	7
7	Explain the impact of harmonics in rotating machines	7
8	Describe the principle of operation and any one control scheme of DVR	7
9	Calculate the required copper metal thickness to attenuate the radiated electromagnetic field (far field) of 1kHz by 100dB? Given that the shield impedance of copper at 1 kHz is 11.6 μΩ and the skin depth of copper at this frequency is 2mm	7
10	Design a line filter to reduce common mode noise by 40dB at 150kHz and differential mode noise by 40dB at 100kHz. Separate common mode and differential mode chokes may be used. Also explain the use of LISN.	7
11	(i) Explain any two techniques to reduce conducted noise pick up in PWM converters (ii) Explain PCB layout considerations to reduce conducted noise.	7

12	Draw the circuit diagram of a forward converter operating at 50kHz, power being drawn from 230V, 50Hz mains. Identify the possible conducted noise emission sources and explain the means to reduce EMI.	7

Syllabus

Module I (7 hrs)

Power Quality (PQ) issues- causes and effects- power frequency disturbances-voltage sag, swell, flicker, IEEE 1453 standard- voltage imbalance and low frequency noise- remedies-isolation transformers- voltage regulators and uninterruptible power supplies-voltage tolerance criteria- power system transient model- transients due to atmospheric conditions, load switching, interruption of fault currents, capacitor bank switching- neutral voltage swing

Module II (7 hrs)

Power system harmonics- causes of current and voltage harmonics- individual and total harmonic distortion- harmonic signature of different loads- lighting- adjustable speed drives, single phase-controlled converters, switch mode power supplies, battery chargers and arc furnaces- effect of harmonics on power system devices- IEEE519 and IEEE1159 harmonic standards, harmonic current mitigation-harmonic cancellation- filters- power quality instrumentation and measurements- case studies

Module III (8 hours)

Overview of mitigation methods- shunt active filters and series active filters- single-phase two-wire, three-phase three-wire, and three-phase four-wire- principle of operation- case studies- D-STATCOM- mitigation of poor power factor, unbalanced currents, and increased neutral current- VSI based three-phase three-wire and four wire DSTATCOM- principle of operation and control - VSI based three-phase three-wire Dynamic voltage restorer- unified power quality conditioner

Module-IV (9 hrs)

Electromagnetic Interferences (EMI) and Electro Magnetic Compatibility (EMC) regulations-IEC61800-3 - CISPR25- conducted and radiated emission mechanisms in power electronic circuits- typical noise path- methods of reducing interference- Capacitive and inductive coupling, Shielding of cables and transformers - ground loops- testing of conducted EMI- LISN-Near and far fields, characteristic and wave impedances, shielding effectiveness- conducted emissions- power line filters-common mode choke - design- magnetic field emissions- system design for EMC

Module-V (9 hrs)

Power supply decoupling- transient power supply current and load current- Fourier spectrum-decoupling capacitors- target impedance- effect of decoupling on radiated emissions- PCB layout considerations- PCB to chassis ground connection- multilayer boards, mixed-signal PCB layout considerations- mixed-signal power distribution- Electrostatic Discharge (ESD) -Static generation, human body model, ESD protection in equipment design, Transient and Surge Protection Devices

Syllabus and Course Plan

No	Topic	No. of Lectures
1	Power Quality (PQ) issues- causes and effects- power frequency disturbances-voltage sag, swell, flicker, voltage imbalance and low frequency noise-remedies- isolation transformers- voltage regulators and uninterruptible power supplies-voltage tolerance criteria- power system transient model-transients due to atmospheric conditions, load switching, interruption of fault currents, capacitor bank switching- neutral voltage swing	
1.1	Power Quality (PQ) issues- causes and effects	1
1.2	power frequency disturbances-voltage sag, swell, flicker, voltage imbalance and low frequency noise- remedies-	2
1.3	isolation transformers- voltage regulators and uninterruptible power supplies	1
1.4	Voltage tolerance criteria- power system transient model-transients due to atmospheric conditions, load switching,	1
1.5	Interruption of fault currents, capacitor bank switching-neutral voltage swing	2
2	Power system harmonics- causes of current and voltage harmonics-individual and total harmonic distortion- harmonic signature of different loads- lighting- adjustable speed drives, single phase controlled converters, switch mode power supplies, battery chargers and arc furnaces- effect of harmonics on power system devices- IEEE519 harmonic standards, harmonic current mitigation-harmonic cancellation- filters- power quality instrumentation and measurements- case studies	
2.1	Power system harmonics- causes of current and voltage harmonics	1
2.2	Individual and total harmonic distortion- harmonic signature of different loads- lighting- adjustable speed drives, single phase-controlled converters, switch mode power supplies, battery chargers and arc furnaces	1
2.3	Effect of harmonics on power system devices- IEEE519 harmonic standards	2

2.4	Harmonic current mitigation-harmonic cancellation- filters	1
2.5	Power quality instrumentation and measurements- case studies	2
3	Overview of mitigation methods- shunt active filters and series active filters- single-phase two-wire, three-phase three-wire, and three-phase four-wire- principle of operation- case studies- D-STATCOM- mitigation of poor power factor, unbalanced currents, and increased neutral current- VSI based three-phase three-wire and four wire DSTATCOM- principle of operation and control- - VSI based three-phase three-wire Dynamic voltage restorer- unified power quality conditioner	
3.1	Overview of mitigation methods- shunt active filters and series active filters	1
3.2	single-phase two-wire, three-phase three-wire, and three-phase four-wire- principle of operation- case studies	2
3.3	D-STATCOM- mitigation of poor power factor, unbalanced currents, and increased neutral current	1
3.4	VSI based three-phase three-wire and four wire DSTATCOM- principle of operation and control	2
3.5	VSI based three-phase three-wire Dynamic voltage restorer	1
3.6	Unified power quality conditioner	1
4	Electromagnetic Interferences (EMI) and Electro Magnetic Compatibility (EMC) regulations- IEC61800-3- CISPR25- conducted and radiated emission mechanisms in power electronic circuits- typical noise path- methods of reducing interference- Capacitive and inductive coupling, Shielding of cables and transformers - ground loops- testing of conducted EMI- LISN- Near and far fields, characteristic and wave impedances, shielding effectiveness- conducted emissions- power line filters-common mode choke - design- magnetic field emissions- system design for EMC	
4.1	Electromagnetic Interferences (EMI) and Electromagnetic Compatibility (EMC) regulations- IEC61800-3- CISPR25-	2
4.2	Conducted and radiated emission mechanisms in power electronic circuits- typical noise path- methods of reducing interference	1
4.3	Capacitive and inductive coupling	1
4.4	Shielding of cables and transformers- ground loops-	1
4.5	Testing of conducted EMI- LISN	1
4.6	Near and far fields, characteristic and wave impedances, shielding effectiveness- conducted emissions	1
4.7	Power line filters-common Mode Choke - design- magnetic field emissions- system design for EMC	2
5	Power supply decoupling- transient power supply current and load current- Fourier spectrum- decoupling capacitors- target impedance- effect of decoupling on radiated emissions- PCB layout considerations- PCB to chassis ground connection- multilayer boards, mixed-signal PCB layout considerations- mixed-signal power distribution- Electrostatic Discharge (ESD) - Static generation, human body model, ESD protection in equipment design, Transient and Surge Protection Devices	
5.1	Power supply decoupling- transient power supply current	2

	and load current-Fourier spectrum- decoupling capacitors	
5.2	Target impedance- effect of decoupling on radiated emissions	1
5.3	PCB layout considerations- PCB to chassis ground connection- multilayer boards, mixed-signal PCB layout considerations	2
5.4	Mixed-signal power distribution	1
5.5	Electrostatic Discharge (ESD) - Static generation, human body model, ESD protection in equipment design	2
5.6	Transient and Surge Protection Devices	1

References:

1. C. Sankaran - Power Quality, CRC, 2001
2. Alexander Kusko, Marc T.Thompson, “Power Quality in Electrical Systems”, McGrawHill, 2007
3. Francois Costa et al., “Electromagnetic compatibility in Power Electronics”, Wiley Iste, 2014
4. Power Quality Problems and Mitigation Techniques”, “Bhim Singh, Ambrish Chandra and Kamal Al-Haddad, Wiley, 2015
5. Henry W.Ott, “Electromagnetic Compatibility Engineering”, Wiley Interscience,2009
6. H.W. Whittington, “Switched Mode Power Supplies: Design and Construction”, Wiley, 1997
7. A Ghosh, G. Ledwich, Power Quality Enhancement Using Custom Power Devices. Kluwer Academic, 2002
8. Jos Arrillaga, Neville R Watson, “Power system harmonics” 2nd edition Wiley

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221LEE002	ADVANCED POWER ELECTRONICS AND MACHINES LAB	Laboratory 1	0	0	2	1

Preamble: Nil
Prerequisites: Nil

Course Objectives
Course Outcomes:
After the completion of the course, the student will be able to
1. Develop the gate drive circuits for various power electronic systems.
2. Analyse the losses in power switches.
3. Design and implementation DC to DC converters
4. To analyse the performance of power converters
5. To study the computer simulation of electrical machines and drives.

LIST OF EXPERIMENTS
LIST OF EXPERIMENTS Power Electronics:
1. Design and Implementation of Drive Circuits for Power MOSFET
2. Design and develop an experiment for switching loss and conduction loss measurement for MOSFET
3. Inductor design for DC-to-DC converter and parameter measurement using different methods.
4. Design and implementation of H bridge using the PWM technique
5. To design and develop a Triggering circuit for a fully controlled converter
6. Performance evaluation of Controlled rectifiers
7. Study of Sine-Triangle PWM: Analog and Digital Implementation.
8. Performance evaluation of Inverters: Stepped wave and PWM inverters.
9. Current Sensing using Hall Effect Sensors. Design and testing of LEM/equivalent make current sensor-based sensing circuit.
10. Performance evaluation of Single-phase AC voltage controller.

LIST OF EXPERIMENTS computer simulations:
1. Modelling of dc machines using computer simulation packages.
2. Modelling of ac machines using computer simulation packages
3. Transfer function of a DC Motor& AC motor
4. Simulation of Three Phase Bridge Inverters with SPWM
5. Speed Control of Induction Motor using AC Voltage Controllers
6. Performance evaluation of Single-phase Semi converters and Full converters
7. Performance evaluation of DC-DC Choppers using SCRs and Self communicating Devices.
8. Performance evaluation of Single phase and three phase inverters using IGBTs,
9. Performance evaluation of Inverters: Stepped wave and PWM inverters.
10. . Performance evaluation of AC-AC voltage regulators.
11. . Performance evaluation of DC and AC drives

Major Equipment Required
a. Single phase Thyristor Converter and its Firing circuit
b. Three-phase Thyristor Converter and its Firing circuit
c. Commutation circuit
d. Single phase and Three phase Bridge Inverter and its firing circuit
e. Control of separately excited dc motor drives open loop & closed loop kit
f. MATLAB