SEMESTER I

Discipline : ELECTRICAL & ELECTRONICS
Stream: EE2 (Power Electronics and Power Systems, Power Electronics and Drives, Power Electronics, Power Electronics and Control, Electrical and Electronics Engineering)

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	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 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 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 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

STREAM:

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 $S = \{v_1, v_2, \ldots, v_n\}$ 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) $\parallel f \parallel, \parallel g \parallel$ 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 - Initial conditions 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 observer controller configuration	2

221TEE001	ANALYSIS OF POWER ELECTRONIC CIRCUITS	CATEGORY	L	T	P	CREDIT
		Program Core 1	3	0	0	3

Preamble: This course aims to provide a strong foundation about gate drive circuits, Controlled Converters and PWM inverters. This course includes its applications to DC and AC drives.

Prerequisites: Nil

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

CO 1	Develop various gating circuits and illustrate the operation of choppers
CO 2	Analyse the operation of controlled and PWM rectifier circuits.
CO 3	Select the control schemes for Voltage Source and Current Source inverters
CO 4	Distinguish the operation and control schemes for Current regulated VSI, Z-source Inverter and Matrix converters.
CO 5	Summarize the performances of induction motor drives and various types of inverters.

Mapping of course outcomes with program outcomes

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

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:

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 a 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 A and Part B.
Part A contains 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 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	**Slot B**
APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY		
FIRST SEMESTER M.TECH DEGREE EXAMINATION MONTH & YEAR		
Course code: 221TEE001	Course Name: ANALYSIS OF POWER ELECTRONIC CIRCUITS	
Max. Marks: 60		Duration: 2.5 Hours

PART A				
Answer all Questions. Each question carries 5 Marks				
Sl. No	Question	Marks	CO	BL
1	Illustrate two quadrant operation of chopper controlled separately excited DC motor drive with the circuit diagram and waveforms.	5	1	3
2	With the circuit diagram of a single-phase dual converter fed separately excited DC drive in circulating current mode, obtain the relationship between firing angles.	5	2	3
3	Compare unipolar and bipolar PWM techniques for single phase inverter	5	3	5
4	With the scheme of hysteresis current control, sketch the block diagram of the current regulated voltage source inverter. Also illustrate the principle of operation	5	4	4
5	Compare the multilevel inverters diode clamped and flying capacitor type on its topologies	5	5	5
PART –B				
(Answer any five questions, each question carries 7 marks)				
6	Design and develop a digital gate drive circuit to trigger a MOSFET IRF540 suitable for a step up converter with an input voltage of 24V, output voltage of 48V. Also explain the operation of the gate drive circuit.	7	1	6
7	(a) Derive an expression for RMS output voltage of a single-phase semi converter with RL load	3	2	4
	(b) Obtain the firing angle for the above converter with an input sinusoidal voltage of 230V RMS and average output voltage of 193V.	4	2	4

8	(a) With the circuit diagram and waveforms of the IGBT based current source inverter illustrate the working.	3	3	3
	(b) With the block diagram explain the operation of closed loop slip Controlled CSI Drive with Regenerative Braking	4	3	4
9	Draw the block diagram of current regulated voltage source inverter with waveform and explain the operation	7	4	3
10	How to overcome the drawbacks of traditional voltage source inverters using Z-source inverters. Draw the circuit diagram and illustrate the operation	7	4	3
11	In variable frequency control of the induction motor drive the V/f ratio is kept constant below base speed and V is constant above base speed. Examine the reason	7	5	3
12	Along with circuit diagram and waveforms discuss the working of cascaded multilevel inverter	7	5	4

Syllabus

Module 1 (8 hrs)

Introduction to Modern Power Electronics - Gate drive circuits for Power Transistor, MOSFET and IGBT. Power dissipation and selection of heat sink. Choppers: Step-down and step-up choppers –PWM control - analysis with RL & RLE load – two-quadrant chopper – Regenerative braking of Separately Excited DC (SEDC) motor - four-quadrant chopper.

Module 2 (8 hrs)

Controlled and PWM Rectifiers: Single-phase semi & full converters – analysis – input PF – inversion mode -3-phase full converters - effect of source inductance on 1-phase & 3-phase full converters - Twelve-pulse converter- Single-phase dual converter fed SEDC motor drive – circulating & non-circulating current operation.
Single phase and 3-phase PWM rectifier – control schemes – hysteresis and PWM control

Module 3 (8 hrs)

PWM Inverters: Need for PWM - Voltage Source Inverter (VSI)- sinusoidal PWM – linear & over modulation - bipolar & unipolar PWM– DC link current - selection of filter capacitor– effect of blanking time- common mode voltage - Third harmonic injection PWM - Space Vector Modulation.
Current source inverter –IGBT based CSI – single phase and three phase- current control

Module 4 (8 hrs)

Current Regulated PWM VSI - Variable Band and Fixed Switching frequency hysteresis current Control
Z-source inverter – equivalent circuit & operation – shoot through zero state – modulation index and boost factor- Simple boost control
Matrix converter –types- principle – switches for matrix converters - 3-phase matrix converter - Venturini control method- Protection circuits

Module 5 (8 hrs)

Inverter fed three Phase Induction motor drives- Torque Equation- Equivalent circuit- V/F control using VSI and CSI -analysis

Multilevel inverters – Diode-clamped multilevel inverter – Flying-capacitors multilevel inverter – cascaded multilevel inverter – PWM for multilevel inverters – comparison.

Course Plan

No	Topic	No. of Lectures
1	**Module 1**	
1.1	Introduction to Modern Power Electronics	1
1.2	Gate drive circuits of Power Transistor	1
1.3	Gate drive circuits of MOSFET, IGBT.	1
1.4	Power dissipation and selection of heat sink.	1
1.5	Step-down and step-up choppers	1
1.6	PWM control – Step down chopper analysis with RL & RLE load	1
1.7	two-quadrant chopper - four-quadrant chopper drive	1
1.8	Regenerative braking of Separately Excited DC motor drive	1
2	**Module 2**	
2.1	Single-phase semi & full converters - inversion	1
2.2	analysis – input PF	1
2.3	3-phase full converter	1
2.4	effect of source inductance on 1-phase & 3-phase full converters - Twelve-pulse converter.	2
2.5	Single phase dual converter fed SEDC motor drive– circulating & non circulating current operation.	1
2.6	Single phase and 3-phase PWM rectifier – control schemes – hysteresis and PWM control	2
3	**Module 3**	
3.1	Pulse Width Modulation (PWM) Strategies for Inverters: Need for PWM - sinusoidal PWM	1
3.2	bipolar & unipolar voltage switching – DC link current - linear & over modulation -	2
3.3	effect of blanking time on voltage in PWM inverter - common mode voltage - selection of filter capacitor	1
3.4	Third harmonic injection PWM - Space Vector Modulation	2
3.5	Current source inverter –IGBT based CSI – single phase and three phase- current control	2
4	**Module 4**	
4.1	Current Regulated PWM VSI - Variable Band	1
4.2	Fixed Switching frequency -hysteresis current Control	1
4.3	Z-source inverter – equivalent circuit & operation – shoot through zero state	2
4.4	Modulation index and boost factor- Simple boost control	1
4.5	Matrix converter – principle – switches for matrix converters -	2
4.6	Venturini method - Protection circuits	1
5	**Module 5**	
5.1	Inverter fed three Phase Induction motor drives- Torque Equation- Equivalent circuit	1
5.2	V/F control using VSI - analysis	1
5.3	CSI - analysis	2

5.3	Multilevel inverters – Diode-clamped multilevel inverter	1
5.4	Flying-capacitors multilevel inverter	1
5.5	cascaded multilevel inverter	1
5.6	PWM for multilevel inverters – comparison.	1

Reference Books

1. Ned Mohan et.al, Power Electronics., John Wiley and Sons ,2007
2. Joseph Vithayathil, "Power Electronics- Principles and Applications", Mcgraw Hill, 1993
3. G K Dubey Fundamentals of Electric Drives Narosa Publishers
4. M. H. Rashid, Power Electronics, PHI, 2005
5. Robert W. Erickson and Dragan Maksimovic, 'Fundamentals of Power Electronics, Springer, 2nd Edition,2013.
6. Barry Williams, "Principles and Elements of Power Electronics", University of Strathclyde.
7. William Shepherd & Li Zhang, "Power Converter Circuits", Marcel Dekker Inc,2004.
8. Fang Lin Luo & Hong Ye, "Power Electronics, Advanced Conversion Technologies", CRC Press,2010.
9. D. Grahame Holmes, Thomas A Lipo, Pulse Width Modulation for Power converters- Principles and Practice, John Wiley and sons, 2003.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221TEE002	**SWITCHED MODE POWER CONVERTERS**	**Program Core 2**	**3**	**0**	**0**	**3**

Preamble:
The key aspect of power electronics is the efficiency of power processing. Switched converters offer power conversion at high efficiency. This course equips the students to model and analyse the performance of isolated and non-isolated switched mode dc-dc converters. This course also covers various control techniques and switching topologies used in power converters.

Prerequisites: Nil

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

CO 1	Analyse the performance of non-isolated switched mode dc-dc converters
CO 2	Model different second order switched mode power converters and design suitable compensators
CO 3	Analyze and appraise various isolated DC-DC converter topologies
CO 4	Evaluate the performance of current controlled switched mode power converters
CO 5	Design various resonant converter switching topologies

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				
CO 2	3	2	3	2	2		
CO 3	3	2	3	2	2	2	
CO 4	2	2	2				
CO 5	2	2	2				

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: 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:

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contains 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 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

Slot: C

APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M. TECH DEGREE EXAMINATION

MONTH & YEAR

Course code: **221TEE002**

Course Name: **SWITCHED MODE POWER CONVERTERS**

Max. Marks: 60 **Duration: 2.5 Hours**

PART A
Answer all Questions. Each question carries 5 Marks

1. For an ideal buck-boost converter, derive the value of L in terms of duty cycle, switching frequency and load at the boundary of discontinuous conduction mode (DCM) and continuous conduction mode (CCM).
2. Explain the voltage mode control of SMPS
3. In a flyback converter, the ratio of average input to output current is 10/3 while operating with a duty ratio of 0.6. What is the ratio of maximum voltage seen by diode in secondary side to maximum voltage seen by primary side switch?
4. Explain the One Cycle Control technique used in dc-dc converters
5. Differentiate between ZVS and ZCS topologies

PART –B
(Answer any five questions, each question carries 7 marks)

6. A boost converter has an input voltage of Vd=10V and an average output voltage of 20V and average load current of I0=0.5A. The switching frequency is 25kHz and and L=200µH and C=220µF.Determine (a) duty ratio (b) ripple current of the inductor (c) peak current of inductor and (d) ripple voltage of capacitor.
7. Explain the method of averaging state variable description using duty ratio for buck and boost converter topologies
8. A forward converter has the following parameters.

V_s= 48V, R =10 Ω, L_x = 0.4mH, L_m = 5mH, C = 100µF, f = 35khz, N1/N2 = 1.5
N1/N3 = 1, D = 0.4

Determine (a) output voltage (b) average current in Lx (c) maximum and minimum current in Lx (d) peak current in the transformer primary winding (e) verify that the magnetizing current is reset to zero during each switching period. Assume all components are ideal.

9. Describe the operation of a push pull converter with waveforms. Discuss the flux imbalance problems in this converter.

10. Explain the operation of Current Mode PWM Control IC - UC3842.

11. Describe the working of series load resonant converter in discontinuous conduction mode 12. Illustrate the working of ZCS resonant switch converter

SYLLABUS

Module I (9 Hrs)

DC-DC non-isolated converters: Buck, Boost, Buck-Boost converters in continuous and discontinuous conduction mode - analysis and design; CUK and SEPIC converters - operation in continuous conduction mode; Comparison of converters; Selection of components; Switching and conduction losses; Design of snubber and heat sink.

Module II (9 Hrs)

Modelling and Control of second order switched mode power converters: State space averaging and linearization, Small signal approximation and circuit averaged model; Voltage Mode control - Transfer Functions; Stability; Design of compensators; Loop gain and stability considerations.

Module III (8 Hrs)

Isolated DC-DC converters: Push-Pull and Forward Converter Topologies, Half and Full Bridge Converters, Flyback Converter - Basic Operation, Waveforms - Flux Imbalance issues - Transformer Design - Output Filter Design - Switching Stresses and Losses - Design of Magnetics; Voltage Mode Control - Study of a typical Voltage Mode PWM Control IC-SG3525.

Module IV (7 Hrs)

Current Mode Control: Advantages, Current Mode vs. Voltage Mode, Slope compensation, one cycle control; Current programmed control of DC-to-DC converters- sub-harmonic instability- compensation to overcome sub-harmonic instability; Determination of duty ratio for current programmed control-buck, boost, buck-boost converters; Current measurement, EMI issues, protection. Layout considerations. Study of a typical Current Mode PWM Control IC - UC3842.

Module V (7 Hrs)

Resonant Converters: Classification, Resonant Switch Converter, Zero Voltage Switching- design, Zero current switching - design, ZVS Clamped Voltage Topologies, Load Resonant Converter, LLC Resonant Converter - Study of a typical resonant Control IC-UCC256304.

COURSE PLAN

No	Topic	No. of Lectures
1	**DC-DC non-isolated converters**	
1.1	Buck converter in continuous and discontinuous conduction-Analysis and Design	1
1.2	Boost converter in continuous and discontinuous conduction-Analysis and Design	1
1.3	Buck-Boost converter in continuous and discontinuous conduction-Analysis and Design	1
1.4	CUK and SEPIC converters- operation in continuous conduction mode	2
1.5	Comparison of the converters	1
1.6	Selection of components, switching and conduction losses	1
1.7	Design of Snubber and heat sink	2
2	**Modelling and Control of second order switched mode power converters**	
2.1	State space averaging and linearization	1
2.2	Small signal approximation and circuit averaged model	2
2.3	Voltage Mode Control-Transfer Functions- Output to input transfer function, Output to state transfer function	2
2.4	Design of compensator, Stability	2
2.5	Voltage mode control of SMPS	1
2.6	Loop gain and stability considerations	1
3	**Isolated DC-DC converters**	
3.1	Push-Pull and Forward Converter Topologies: Basic Operation, Waveforms	2
3.2	Half and Full Bridge Converters: Basic Operation, Waveforms	2
3.3	Flyback Converter: Basic Operation, Waveforms	1
3.4	Flux Imbalance issues - Transformer Design -Output Filter Design	1
3.5	Switching Stresses and Losses -Design of Magnetics	1
3.6	Voltage Mode Control-Study of a typical Voltage Mode PWM Control IC-SG3525	1
4	**Current Mode Control**	
4.1	Current Mode Control-Advantages, Current Mode vs. Voltage Mode	1
4.2	Slope compensation	1
4.3	One cycle control	1
4.4	Current programmed control of DC-to-DC converters- sub-harmonic instability- compensation to overcome sub-harmonic instability;	1
4.5	Determination of duty ratio for current programmed control-buck, boost, buck-boost converters;	1

4.6	Current measurement, EMI issues, protection, Layout considerations.	1
4.7	Study of a typical Current Mode PWM Control IC - UC3842	1
5	**Resonant Converters**	
5.1	Resonant Converters- Classification	1
5.2	Resonant Switch Converter	1
5.3	Zero Voltage Switching & Zero current switching-design	2
5.4	ZVS Clamped Voltage Topologies	1
5.5	Load Resonant Converter	1
5.6	LLC Resonant Converter-Study of a typical resonant Control IC-UCC256304.	1

Reference Books

1. Mohan, Undeland, Robbins, Power Electronics – Converters, Applications and Design, Wiley-India, 1995.
2. Prof. V. Ramanarayanan, Course Material on Switch Mode Power Conversion, Electrical Department, IISc, Bangalore, 2006.
3. Daniel W. Hart, Power Electronics, Tata McGraw-Hill, 2011
4. Robert. W. Ericson, Fundamentals of Power Electronics, Springer, 1997.
5. Abraham I Pressman, Switching Power Supply Design. McGrawHill, 1998.
6. William Shepherd, Li Zhang, Power Converter Circuits, Marcel Decker, 2004.
7. Keith Billings, Switched mode power supply handbook, McGraw-Hill, 1998.
8. George Chryssis, High frequency switching power supplies-theory and design, McGraw-Hill, 1988.
9. Philip T Krein, Elements of Power electronics, Oxford university press, 1998.

221EEE100	Advanced Power Semiconductor Devices	CATEGORY	L	T	P	CREDIT
		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.

Prerequisites: Nil

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

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	1

	devices -characteristics- static and dynamic	
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 & Year

221EEE100– 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)
8. (a) Explain the switching characteristics of P channel MOSFET (4 marks)
(b)Calculate the total power loss for the MOSFET having the following parameters: 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)

221EEE018	DYNAMICS OF LINEAR SYSTEMS	CATEGORY	L	T	P	CREDIT
		Program Elective 1	3	0	0	3

Preamble:
This course includes state space description of continuous time systems, state observers, design of controllers using QFT, Analysis of system sliding mode control and optimal control.

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	Analyse different state space realisations of continuous and discrete time systems and choose appropriate forms for a given application
CO 2	Design and analysis of controllers and/or observers for a given system
CO 3	Design of controllers in the frequency domain / using Quantitative Feedback Theory
CO 4	Study of controllability and observability for MIMO systems
CO 5	Design of sliding mode controller for continuous system
CO 6	Design of optimal controller and observer for a given system and evaluate its performance

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	1	
CO 2	2	1	3	3	2	1	
CO 3	2	1	3	3	2	1	
CO 4	2	1	3	2	2	1	
CO 5	2	1	3	2	2	1	
CO 6	2	1	3	3	2	1	

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:
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 (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

221EEE018 DYNAMICS OF LINEAR SYSTEMS		
Time: 2.5 hours		**Max.Marks:60**
Part A (Answer all questions)		**5x5=25 marks**
1	Consider the system function given below $$G(s) = \frac{(s+5)}{(s+2)(s^2+3s+4)}$$ Obtain state models by direct and cascade decompositions.	5
2	What do you mean by the duality principle related to controllability and observability? Analyse duality principle with an example.	5
3	Explain the pole placement problem of MIMO systems.	5
4	Explain the reaching laws associated with conventional sliding mode control.	5
5	Explain time optimal control of continuous time systems with unbounded control input.	5
Part B (Answer any five questions)		**7x5=35 marks**
6	How will you obtain the solution of a state equation? Obtain the solution, of the state equation given by $$\dot{x} = [0\ 1\ -2\ -3\,]x + [2\ 5\,]u$$ y = [1 2] x	7
7	A regulator system has the plant $\dot{X} = \begin{bmatrix} 0 & 20.6 \\ 1 & 0 \end{bmatrix} X + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$. The closed loop poles are to be placed at $s = -2 \pm j2\sqrt{3}$. Design a controller and observer so that observer error poles are placed at $s = -1.8 \pm j2.4 s = -1.8 \pm j2.4$. Draw the complete state block diagram	7
8	Design a state observer to the given system such that the observer eigen values are at μ = -2 $\pm j2\sqrt{3}$, μ = -5. The system is given as $$\dot{x} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ -6 & -11 & -6 \end{bmatrix} x + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u$$	7

	y = [1 0 0] x	
9	Explain the steps involved in deriving the controllable companion form of MIMO systems.	7
10	Explain any one method of designing a sliding surface for SMC.	7
11	Design a stabilising variable structure control for a double integrator system	7
12	Determine the optimal control function u for the system described by $$\dot{x} = Ax + Bu$$ Where, $$x = [x_1\ x_2],\ A = [0\ 1\ 0\ -1],\ B = [0\ 1]$$ Such that the following performance equation is minimised: $J = \int_0^\infty (x'x + u'u)dt$	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 the third semester can have content for 30 hours).

Review of State Variables: Motivation for State Variables, Implementation of Differential Equations, State space description of continuous time systems, the state transition matrix, non-homogeneous equations

MODULE I (8hours)

Review of state space representation of continuous and discrete time systems, Basic Realization Theory: Similarity Transformation, Canonical Realizations, Jordan and real canonical forms, Minimal realization, Connections to Transfer Functions: Characteristic/Minimal Polynomials, matrix exponentials

MODULE II (8hours)

Observability and state Observers for un-measurable state measurement, Stability and time response, State Controllability, Canonical Realizations Duality, Decomposition of Uncontrollable and Unobservable realizations, Popov test, State Feedback Asymptotic Observers: Full and reduced order, Separation Principle and Pole Placement Theorem.

MODULE III (8 hours)

Direct transfer function design procedures – Design using polynomial equations - Direct analysis of the Diophantine equation. MIMO systems: Introduction, controllability, observability, different companion forms for MIMO.

Introduction to Quantitative feedback theory (QFT) and design of controllers using QFT

MODULE IV (9 hours)

Introduction to variable structure systems, definition of variable structure and sliding mode, examples of dynamics system with sliding modes, differential equations with discontinuous right-hand sides, Concept of a manifold, sliding surface, sliding mode motion and sliding mode control

MODULE V (7 hours)

Optimal control - formulation of optimal control problem - Minimum time control problem - minimum energy problem - minimum fuel problem - state regulator problem - output regulator problem – tracking problem - choice of performance measure - optimal control based on quadratic performance measure – optimal control system design using second method Lyapunov - solution of reduced Riccatti equation.

Course Plan

No	Topic	No. of Lectures
1	Review of state space representation of continuous and discrete time systems	
1.1	state space representation review-Similarity Transformation	2
1.2	Canonical Realizations	1
1.3	Jordan and real canonical forms- Minimal realization	2
1.4	Connections to Transfer Functions- Characteristic/Minimal Polynomials	2
1.5	matrix exponentials	1
2	Observability and state Observers for un-measurable state measurement	
2.1	Stability and time response, State Controllability	1
2.2	Canonical Realizations Duality	1
2.3	Decomposition of Uncontrollable and Unobservable realizations	2
2.4	Popov test	1
2.5	State Feedback Asymptotic Observers: Full and reduced order	2
2.6	Separation Principle and Pole Placement Theorem	1
3	Direct transfer function design procedures	
3.1	Design using polynomial equations	1
3.2	Direct analysis of the Diophantine equation.	2
3.3	MIMO systems: Introduction- controllability	1
3.4	Observability- different companion forms for MIMO	1
3.5	Introduction to Quantitative feedback theory	1
3.6	design of controllers using QFT	2
4	Introduction to variable structure systems	
4.1	definition of variable structure and sliding mode, examples of dynamics system with sliding modes	3
4.2	differential equations with discontinuous right-hand sides	3
4.3	Concept of a manifold, sliding surface, sliding mode motion and sliding mode control	3
5	Optimal control-	
5.1	formulation of optimal control problem - Minimum time control problem -minimum energy problem	2
5.2	state regulator problem - output regulator problem – tracking problem	2
5.3	choice of performance measure - optimal control based on quadratic performance measure	1
5.4	optimal control system design using second method Lyapunov - solution of reduced Riccatti equation	2

References

1. Thomas Kailath, “Linear System”, Prentice Hall Inc., Eaglewood Cliffs, NJ, 1998
2. M. Gopal,”Control Systems-Principles and Design”, Tata McGraw-Hill.
3. Richard C. Dorf & Robert H. Bishop, “Modern Control Systems”, Pearson Education, Limited, 12th Ed., 2013
4. Gene K. Franklin & J. David Powell, “Feedback Control of Dynamic Systems”, Pearson Education, 5th Edition, 2008
5. Friedland B., “Control System Design: An Introduction to State Space Methods”, Courier Corporation, 2005
6. C.T. Chen, “Linear System theory and design”, Holt, Rinehart and Winston, New York, 1984, xxii,662.
7. Isaac M. Horowitz: Quantitative feedback Design theory, QFT publications, 1992
8. Hebertt Sira-Ramirez,” Sliding Mode Control: The Delta-Sigma Modulation Approach (Control Engineering) “, Springer Nature; 2015th edition (9 June 2015)
9. Panos J. Antsalis, Anthony N Michel,” A linear Systems Primer” Birkhauser Boston.

221EEE002	SOFT COMPUTING TECHNIQUES FOR PE APPLICATIONS	CATEGORY	L	T	P	CREDIT
		Program Elective 1	3	0	0	3

Preamble:
The course attempts to impart knowledge about soft computing techniques intended for Power Electronic (PE) Applications. It also covers basic artificial intelligence techniques such as Fuzzy Logic, Neural Networks, Genetic Algorithms and Hybrid systems with an objective of solving real time issues in Power Electronics circuits. A basic Knowledge of MATLAB software in power electronics is desirable as a prerequisite.

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

CO 1	Analyze power electronics systems with fuzzy logic controller
CO 2	Demonstrate methods of Artificial Neural Networks for the application of Power Electronic converters
CO 3	Analyze Backpropagation neural networks for the application of Power Electronic converters
CO 4	Differentiate GA architectures and describe GA operators and multi objective GA for the application of Power Electronic converters
CO 5	Apply hybrid techniques as per the required environment for the application of Power Electronic converters

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	1	2	-
CO 2	2	-	3	2	1	2	-
CO 3	2	-	3	2	1	2	-
CO 4	2	-	3	2	1	2	-
CO 5	3	-	3	2	1	2	-

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	30%
Analyse	30%
Evaluate	30%
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): 10 marks
Course based simulation and interpretation: 10 marks
Test paper, 2 no.: 20 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: 221EEE002	Course Name: SOFT COMPUTING TECHNIQUES FOR PE APPLICATIONS	
Max. Marks: 60		Duration: 2.5 Hours

	Part A (Answer all questions)	**5x5 =25**
1	Consider two fuzzy sets ⍰ = { 0.2 /0 + 0.3 /1 + 1 /2 + 0.1 /3 + 0.5/ 4 } ⍰ = { 0.1/ 0 + 0.25/ 1 + 0.9 /2 + 0.7 /3 + 0.3/ 4 + 0.2 /5 } Find the following: (i) Algebraic sum (ii) Bounded sum (iii)Bounded Difference	5
2	Explain the different learning mechanisms used in Artificial NeuralNetworks with the help of necessary diagrams.	5
3	What is the objective of back propagation in neural networks?	5
4	“Termination criterion for a genetic algorithm brings the search to a halt”. Explain the various termination techniques	5
5	Write any three advantages of Neuro- Genetic hybrid system.	5
	Part B (Answer any five questions)	**7x5 =35**

6	Illustrate how a phase-controlled rectifier fed dc drive can be controlled using a fuzzy controller. Explain how the dynamic and steady state performance can be improved by proper selection of fuzzy sets and the issues involved	7
7	Illustrate how a multi-layer feed forward neural network controller can be used to control any suitable power electronic converter. Explain how the dynamic and steady state performance can be improved and the issues involved	7
8	i) With graphical representations, explain the activation functions used in Artificial Neural Networks. ii) What is a self-organising map in Kohonen network?	4 3
9	Illustrate how a genetic algorithm-based controller can be used to control any suitable power electronic converter. Explain how the dynamic and steady state performance can be improved and the challenges involved	7
10	Explain the following terms (a) Cooperative Neural Fuzzy Systems (b) General Neuro Fuzzy Hybrid Systems	7
11	Discuss about recurring neural networks (RNN) and explain the speed estimation of motor drives by RNN	7
12	i) Mention the stopping condition for genetic algorithm flow. ii) Difference between uniform and three parent crossovers	3.5 3.5

Syllabus

Module I **8**

Fuzzy Systems: Introduction to Fuzzy Logic (FL), Classical Sets and Fuzzy Sets - Classical Relations and Fuzzy Relations -Membership Functions -Defuzzification -Mamdani and Sugeno type- Fuzzy Rule Base and Approximate Reasoning - Introduction to Fuzzy Decision Making, Special forms of fuzzy logic models -Case studies related to power electronics applications- Fuzzy logic (FL) based control of a phase-controlled converter dc machine drive- Fuzzy speed controller in vector controlled drive system with variable moment of inertia- FL based wind generation- FL based stator resistance estimation of induction motor

Module II **8**

Artificial Neural Networks (ANN): Biological neurons and its working. ANN models - Types of activation function - Introduction to Network architectures - Multi Layer Feed Forward Network (MLFFN) - Radial Basis Function Network (RBFN) - Recurrent Neural Network (RNN)- Case studies related to power electronics applications- ANN based selective harmonic Elimination (SHE) PWM- ANN based instantaneous current control of three phase inverter- ANN based rotor flux estimation- Speed estimation by RNN- Harmonic detection based on RBFN

Module III **8**

Other Types of ANN: Back propagation Neural Networks - Kohonen Neural Network -Learning Vector Quantization -Hamming Neural Network – Hopfield Neural Network- Bi- directional Associative Memory -Adaptive Resonance Theory Neural Networks- Support Vector Machines - Spike Neuron Models - Case studies related to power electronics applications.

Module IV **8**

Genetic Algorithm: Concept of "Genetics" and "Evolution", Basic GA framework and different GA architectures, GA operators: Encoding, Crossover, Selection, Mutation. Solving single-objective optimization problems using GAs, Multiobjective GA - Case studies related to power electronics applications.

Module V **8**

Hybrid Systems: Adaptive Neuro fuzzy Inference System (ANF1S), Neuro –Genetic, Fuzzy-Genetic systems. Coactive Neuro-Fuzzy Modelling: Towards Generalized ANFIS.

GA Based Weight Determination - LR-Type Fuzzy Numbers - Fuzzy Neuron - Fuzzy BP Architecture. Particle Swarm Optimization - Case studies related to power electronics applications

Course Plan

No	Topic	No. of Lectures
	Module I	
1.1	Fuzzy Systems: Introduction to Fuzzy Logic, Classical Sets and Fuzzy Sets - Classical Relations and Fuzzy Relations	2
1.2	Membership Functions -Defuzzification	1
1.3	Mamdani and Sugeno type- Fuzzy Rule Base and Approximate Reasoning	1
1.4	Introduction to Fuzzy Decision Making, Special forms of fuzzy logic models	1
1.5	Case studies related to power electronics applications- Fuzzy logic (FL) based control of a phase-controlled converter dc machine drive- Fuzzy speed controller in vector controlled drive system with variable moment of inertia	2
1.6	FL based wind generation- FL based stator resistance estimation of induction motor	1
	Module II	
2.1	Artificial Neural Networks: Biological neurons and its working. ANN models	1
2.2	Types of activation function - Introduction to Network architectures - Multi Layer Feed Forward Network (MLFFN)	2
2.3	Radial Basis Function Network (RBFN) - Recurrent Neural Network (RNN)	2
2.4	Case studies related to power electronics applications- ANN based selective harmonic Elimination (SHE) PWM- ANN based instantaneous current control of three phase inverter	2
2.5	ANN based rotor flux estimation- Speed estimation by RNN- Harmonic detection based on RBFN	1
	Module III	
3.1	Other Types of ANN: Back propagation Neural Networks - Kohonen Neural Network	2
3.2	Learning Vector Quantization - Hamming Neural Network	1
3.3	Hopfield Neural Network- Bi-directional Associative Memory	1
3.4	Adaptive Resonance Theory Neural Networks- Support Vector Machines - Spike Neuron Models	3
3.5	Case studies related to power electronics applications	1
	Module IV	
4.1	Genetic Algorithm: Concept of "Genetics" and "Evolution", Basic GA framework and different GA architectures	2
4.2	GA operators: Encoding, Crossover, Selection, Mutation.	2
4.3	Solving single-objective optimization problems using GAs	1
4.4	Multiobjective GA	1

4.5	Case studies related to power electronics applications	2
	Module V	
5.1	Hybrid Systems: Adaptive Neuro fuzzy Inference System (ANF1S)	2
5.2	Neuro–Genetic, Fuzzy-Genetic systems	1
5.3	Coactive Neuro-Fuzzy Modelling: Towards Generalized ANFIS	1
5.4	GA Based Weight Determination - LR-Type Fuzzy Numbers - Fuzzy Neuron - Fuzzy BP Architecture.	2
5.5	Particle Swarm Optimization	1
5.6	Case studies related to power electronics applications	1

Reference Books

1. Bimal K Bose, "Modern Power Electronics and AC Drives, PHI, 2002
2. Teresa Orlowska, Blaabjerg and Rodriguez, "Advanced and Intelligent Control in Power Electronics and Drives, Springer, 2014
3. Marcian Cirstea, Andrei Dinu, Malcolm McCormick, Jeen Ghee Khor, "Neural and Fuzzy Logic Control of Drives and Power Systems", Newness, 2001
4. Sousa, G.C.D., Bose, B.K.: 'A Fuzzy Set Theory Based Control of a Phase-Controlled Converter dc Machine Drive', IEEE Trans. Ind. Appl., vol. 30, 1994, pp. 34–44
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8. S. N. Sivanandam & S. N. Deepa, "Principles of Soft Computing", 2nd edition, Wiley India, 2008.
9. Timothy J Ross, Fuzzy logic with Engineering Applications, McGraw Hill, New York.
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14. J. M. Zurada, 'Introduction to Artificial Neural Systems', Jaico Publishers, 1992.
15. J S R Jang, C T Sun, Mizutani, Neuro Fuzzy and Soft Computing.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221EEE003	CLASSICAL AND SPECIAL ELECTRICAL MACHINE DRIVES	Program Elective 1	3	0	0	3

Preamble: Electrical Machine drive is an important component in highly efficient versatile systems and products in industries, domestic appliances and e-mobility applications. The course intends to provide a strong background on various methods of speed control schemes in classical and commonly used special electrical machines. After successful completion of this course, the students will be able to apply different speed control schemes for the control of DC motors, Induction motors, Synchronous motors, Stepper motors, Switched reluctance Motors & BLDC motors. They will also be able to select suitable power electronic converters and motors for specific speed control applications. Basic courses on Electrical machines and Power Electronics are desirable as prerequisites for the course.

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

CO 1	Develop speed control schemes for different types of Electrical Machines after understanding pertinent limitations of simple drive schemes
CO 2	Analyse different speed control schemes
CO 3	Select suitable power converters
CO 4	Compare the performance of different speed control schemes and power converters
CO 5	Design suitable drive schemes

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	2	1	3	1	1
CO 2	2	1	2	1	3	1	1
CO 3	2	1	2	1	3	1	1
CO 4	2	1	2	1	3	1	1
CO 5	2	1	2	1	3	1	1
CO 6	2	1	2	1	3	1	1

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:

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/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: 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 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

Module I (8 hrs)
Electric Drives –Introduction- DC motor drives – single phase half and fully controlled rectifier fed separately excited DC (SEDC) motor – discontinuous and continuous modes – regenerative braking-three-phase fully controlled drives- continuous conduction- Dual converter fed drive– rectifier control of series motor – Chopper control of SEDC motor–multiquadrant operation- closed loop speed control

Module II (9 hrs)
Three Phase Induction motor drives- Torque Equation- Equivalent circuit- V/F control - Slip speed controlled VSI and CSI drive – analysis of induction motor fed from non-sinusoidal voltage supply- Static rotor resistance control - Slip power recovery schemes for below and above base speed – Synchronous motor drives - True synchronous mode and self-synchronous mode- load commutated drive

Module III (8 hrs)
Stepper Motor and Drives- Variable reluctance, permanent magnet and hybrid motors- Principle of operation - torque production - Static position error- pull-in and pull-out characteristics- resonance issues- Unipolar and Bipolar drive schemes- Bifilar drives- open loop position control- Starting/stopping rate- Velocity profiling

Module IV (6 hrs)
Switched Reluctance Motors (SRM) and Drives- Principle of operation, Inductance profile -

Torque equation- motoring and regeneration- low speed and high-speed operation- torque-speed characteristics- Energy conversion loop- Energy effectiveness- Power controllers, control schemes- Six switch converter- Split dc supply converter-R dump- C dump converters

Module V (9 hrs)

Brushless DC Motors (BLDC) and drives- Permanent magnet materials and characteristics - principle- Speed-Torque characteristics- Torque Pulsation - Power controllers- Full wave and Half wave- Regeneration- Hall Sensor based control - Sensorless control- third harmonic voltage detection – starting- Permanent Magnet Synchronous Motors (PMSM) and drives - Principle - SPM and IPM machines-Torque equation - Phasor Diagram - Power controllers

Course Plan

No	Topic	No. of Lectures
1	**Module 1 (8 hrs)**	
1.1	Introduction to Electric Drives- Drive components- Efficiency Improvements compared to fixed speed drives	1
1.2	DC motor drives – single phase fully controlled rectifier fed separately excited DC (SEDC) motor - Discontinuous and continuous modes - Analysis	1
1.3	DC motor drives – single phase half-controlled rectifier fed separately excited DC (SEDC) motor - continuous conduction - power factor improvements- Analysis	1
1.4	Regenerative braking of controlled rectifier fed separately excited DC (SEDC) motor- commutation issues	1
1.5	Three-phase fully controlled drives- continuous conduction	1
1.6	Dual converter fed drive- four quadrant operation- dc and ac circulating currents	1
1.7	Rectifier control of series motor	1
1.8	Chopper control of SEDC motor–multiquadrant operation- closed loop speed control	1
2	**Module 2 (9 hrs)**	
2.1	Three Phase squirrel cage Induction motor drives- Introduction- basic equations and equivalent circuit	1
2.2	V/F control - open loop and closed loop	1
2.3	Slip speed controlled VSI and CSI drive	1
2.4	Slip speed controlled VSI and CSI drive	1
2.5	harmonic equivalent circuit- analysis of induction motor fed from non-sinusoidal voltage supply	1
2.6	Three Phase squirrel wound rotor Induction motor drives- Introduction- Static rotor resistance control	1
2.7	Slip power recovery schemes for below and above base speed	1
2.8	Synchronous motor drives - Introduction- Basic equations- True synchronous mode and self-synchronous mode	1
2.9	Load commutated synchronous motor drive	1
3	**Module 3 (8 hrs)**	
3.1	Stepper Motor and Drives- Variable reluctance, permanent magnet and hybrid motors- Introduction	1
3.2	Principle of operation- torque production	1
3.3	Static position error	1
3.4	Pull-in and pull-out characteristics- resonance issues	1
3.5	Bifilar, Unipolar and Bipolar drive schemes	1
3.6	Open loop position control- Starting/stopping rate	1

3.7	Velocity profiling	2
4	**Module 4 (6 hrs)**	
4.1	Switched Reluctance Motors (SRM) and Drives- Principle of operation	1
4.2	Inductance profile - Torque equation	1
4.3	Motoring and regeneration- low speed and high-speed operation- torque vs speed characteristics	1
4.4	Energy conversion loop- Energy effectiveness	1
4.5	Power controllers, control schemes- Six switch converter-	1
4.6	Split dc supply converter-R dump- C dump converters	1
5	**Module 5 (9 hrs)**	
5.1	Permanent magnet materials and characteristics	1
5.2	Brushless DC Motors (BLDC) and drives- Introduction- Principle of operation- modelling	2
5.3	Speed-Torque characteristics- Torque Pulsation	1
5.3	Power controllers- Full wave and Half wave- Regeneration-	1
5.4	Hall Sensor based control -	1
5.5	Sensorless control- third harmonic voltage detection –Starting	1
5.6	Permanent Magnet Synchronous Motors (PMSM) and drives - Principle - SPM and IPM machines	1
5.7	Torque equation - Phasor Diagram - Power controllers	1

References

1. G. K Dubey, “Power Semiconductor Controlled Drives”, Prentice Hall
2. G. K Dubey, “Fundamentals of Electrical Drives”, Narosa Publishers
3. Bimal K Bose, “Modern Power Electronics & AC Drives”, Prentice Hall of India
4. Werner Leonhard, “Control of Electrical Drives”, Springer
5. Kenjo T, Sugawara A, “Stepping Motors and their Microprocessor Control”, Clarendon, Press, Oxford
6. Paul Acarnley, “Stepping motors - a guide to theory and practice”, 4th Edn. IET UK, 2002
7. Miller T J E, “Switched Reluctance Motor and their Control”, Clarendon Press, Oxford
8. R Krishnan, “Permanent Magnet Synchronous and brushless dc drives”, CRC Press, 2010

Model Question paper

	Model Question paper	Slot D
APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY		
FIRST SEMESTER M.TECH DEGREE EXAMINATION MONTH & YEAR		
Course code: 221EEE003	Course Name: CLASSICAL AND SPECIAL ELECTRICAL MACHINE DRIVES	
Max. Marks: 60		Duration: 2.5 Hours

Sl. No	Question	Marks	CO	BL
	PART A			
	Answer all Questions. Each question carries 5 Marks			
1	With necessary circuit diagrams, explain how a non-circulating type dual converter fed separately excited DC drive can outperform a circulating current dual converter. Compare the demerits also.	5	1	1
2	Compare V/F control scheme of IM with slip speed control scheme	5	2	1
3	A three phase, 2 NM, 0.0005Kgm^2, VR stepping motor has 16 stator teeth and 20 rotor teeth and is used to drive a frictional load of 0.2 Nm (a) Draw the approximate holding torque curve and mark the no load equilibrium points (b) What is the static position error at load? (c) What is the stepping rate corresponding to a speed of 30 RPM	5	3	2
4	What do you mean by airgap line, recoil line, and magnet stabilization? Explain why the maximum energy product point is not a preferred operating point. Compare NdFeB, SmCo, Alnico and ceramic magnets for use in permanent magnet machines in terms of the above terms	5	4	1
5	Explain the difference between SPM and IPM in terms of machine inductances and extended speed of operation. Also explain the term 'self-control' in connection with PMSM	5	5	1
	PART –B			
	(Answer any five questions, each question carries 7 marks)			
6	(a) Explain how possibilities of discontinuous conduction are minimized in chopper fed dc drives. Illustrate with a two-quadrant drive.	3	1	1

	(b) Draw the circuit schematic of (i) a three phase half controlled separately excited dc motor drive (ii) three phase full controlled drive and compare the performance in terms of torque ripple and supply power factor	4	1	2
7	(a) Prove that the starting current is approximately constant in V/F control. Compare with stator voltage control	3	2	4
	(b) A 400V, 60 Hz, 1155 RPM, 6 pole, Y connected, 3 phase wound rotor induction motor has the following parameters referred to the stator:Rs=0.12Ω, Rr‟ =0.1Ω, Xs=0.2Ω, Xr‟ =0.15Ω. The stator to rotor turns ratio is 1.2 and the dc link inductor has a resistance of 0.025Ω. The motor speed is controlled by static scherbius drive designed for a speed range of 25% below the synchronous speed. Maximum permissible value of firing angle is 168°. Calculate (i) Transformer turns ratio (ii) Torque for a speed of 900 rpm and α=120° (iii) Firing angle for rated motor torque and speed of 800 RPM	4	2	4
8	(a) With necessary sketches, explain the difference between unifilar drive and bifilar stepper motor drivers	3	3	3
	(b) A three phase VR stepping motor with 50 rotor teeth is operated in one phase on scheme. The pull in rate of the motor on no load is 500 steps/sec. A light load having negligible inertia is directly coupled to the motor shaft. Using a microcontroller/microprocessor the motor is to be controlled such that the shaft is rotated 180˚ in the forward direction exactly in 50ms and back to the original position in the next 100ms . Draw the drive circuit, give sequences for full step operation and write an algorithm for the operation.	4	3	5
9	(a) With necessary sketches and waveforms, explain the difference between R dump and C dump converters for SRM	3	4	3
	(b) A three-phase switched reluctance motor with six stator poles and four rotor poles has a stator pole arc of 28° and a rotor pole arc of 32°. The aligned inductance is 10 mH and the unaligned inductance is 5 mH. Neglect fringing and saturation (a) Draw the cross section of the motor at the aligned and unaligned positions (b) Draw the phase inductance vs. rotor position for all the phases (c) Assuming ideal current waveforms with peak phase current of 2A, plot the instantaneous torque developed vs. rotor position for motoring operation and breaking operation for all the phases.	4	4	5

10	Explain how third harmonic voltages can be used for sensorless control of BLDC motor	3	5	1
	(b) A brushless PM sine-wave motor has an open-circuit voltage of 173 V at its corner-point speed of 3000 r.p.m. It is supplied from a p.w.m. converter whose maximum voltage is 200 V r.m.s. Neglecting resistance and all other losses, estimate the maximum speed at which maximum current can be supplied to the motor	4	5	4
11	(a) Model a BLDC motor in state space and show how simulations can be done in SIMULINK	3	4	5
	(b) Derive the torque-speed characteristics of a BLDC motor and compare with that of a dc shunt motor. If a PM brushless d.c. motor has a torque constant of 0.12 N m/A (i) Estimate its no-load speed in rpm when connected to a 48 V d.c. supply. (ii) If the armature resistance is 0.15 Ω/phase and the total voltage drop in the controller transistors is 2 V, determine the stall current and the stall torque.	4	4	1
12	(a) A 100V, 1000 RPM, 50A separately excited dc motor has an armature resistance of 0.2Ω. It is fed from a chopper with a source voltage of 120V. Assuming continuous conduction, draw the circuit topology and calculate the duty ratio for (i) motoring and (ii) braking operation at rated torque and 600 rpm	3	1	4
	(b)Discuss the harmonic equivalent circuit of a three phase Induction motor and compare the effect of harmonics due to (i) square wave operation and (ii) sine triangle PWM	4	2	2

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221EEE006	COMPUTER APPLICATIONS IN POWER SYSTEMS	Program Elective 2	3	0	0	3

Preamble: Integration of computer applications in load flow and short circuit studies in power system

Prerequisites: Nil

Course Outcomes:

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

CO 1	Apply the concepts of sparse matrix in computer applications for large scale power system analysis.
CO 2	Apply computational techniques to analyse and solve load flow studies.
CO 3	Describe the effects of FACTs devices in load flow studies.
CO 4	Evaluate optimal power flow problem using various solution methods.
CO 5	Analyse the solution methods and techniques involved in short circuit studies.

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	3	3	-	-
CO 2	3	-	3	3	3	-	1
CO 3	2	-	1	1	1	-	-
CO 4	2	-	2	2	1	1	2
CO 5	3	-	3	3	3	-	-

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**	**End Semester Examination**
	1	
Remember		
Understand	10	20
Apply	40	40
Analyse	30	40
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/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: 2**

Reg No:___________________ **Name: ___________________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

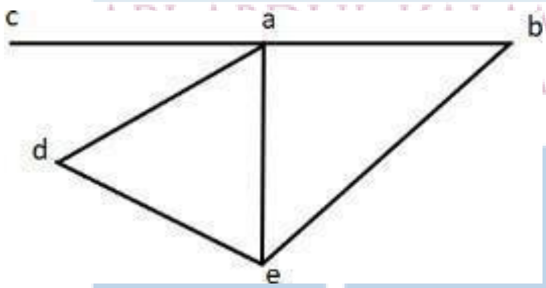
Course Code: 221EEE006

Course name: Computer Applications in Power Systems

Max Marks: 60 **Duration: 2.5 Hours**

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

1. Order the nodes of the given graph in an optimal manner, indicating the necessary steps.

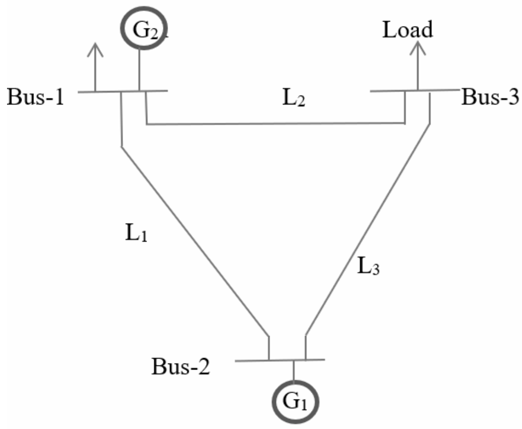


2. Compare Newton Raphson and Fast Decoupled Load flow algorithm
3. Explain the operation of TCSC in a power system.
4. Explain the salient features of Environmental Constrained OPF.
5. Build the Z bus for a three-phase short circuit fault in a power system.

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

6. For the network shown, draw the oriented graph and find the following.

a) Element-node incidence matrix
b) Bus incidence matrix
c) Basic cutset incidence matrix
d) Basic loop incidence matrix

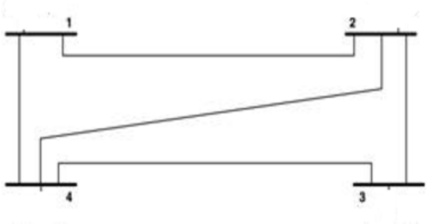


7. Obtain the load flow solution at the end of the first iteration of the power system shown in the figure. The data is provided in the Table. The solution is to be obtained for the following

cases

a) All buses except one are PV buses.

b) Bus 2 is a PV bus where voltage magnitude is specified as 1.04

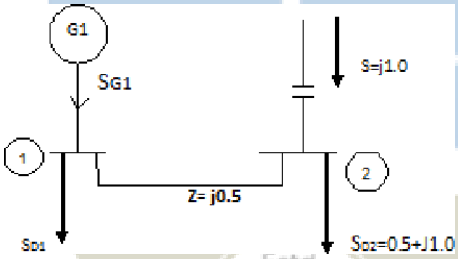


SB	EB	R(pu)	X(pu)
1	2	0.05	0.15
1	3	0.1	0.30
2	3	0.15	0.45
2	4	0.10	0.3
3	4	0.05	0.15

Bus No	P_i(pu)	Q_i(pu)	V_i
1			$1.04\angle 0$
2	0.5	-0.2	
3	-1.0	0.5	
4	-0.3	-0.1	

8. Explain three advantages of incorporating FACTS devices in a power system. Support with an example.

9. Obtain the voltage at Bus-2 for the power system shown in the figure. Use the Gradient method, if V1 =1+ j0.0 (3 iterations)



10. How is Particle Swarm Optimization useful while arriving at an optimal Power Flow?

11. The positive, negative and zero sequence bus impedance matrices of a power system are shown below. A double line to ground fault with Zf=0, occurs at Bus 4. Find the fault current and voltages at faulted buses.

$$Z_{bus}^{(1)} = Z_{bus}^{(2)} = j\begin{bmatrix} 0.1437 & 0.1211 & 0.0789 & 0.0563 \\ 0.1211 & 0.1696 & 0.1104 & 0.0789 \\ 0.0789 & 0.1104 & 0.1696 & 0.1211 \\ 0.0563 & 0.0789 & 0.1211 & 0.1437 \end{bmatrix} \qquad Z_{bus}^{(0)} = j\begin{bmatrix} 0.19 & 0 & 0 & 0 \\ 0 & 0.08 & 0.08 & 0 \\ 0 & 0.08 & 0.58 & 0 \\ 0 & 0 & 0 & 0.19 \end{bmatrix}$$

(rows and columns numbered 1, 2, 3, 4)

12. A 20MVA, 13.8 kV generator has a direct axis sub transient reactance of 0.25pu. Its negative sequence reactance is 0.35 pu and the zero-sequence reactance is 0.1pu. The neutral of the generator is grounded. Find the single line fault current, line to ground voltage.

Syllabus

No	Computer applications in power systems	Contact hours
1	Sparsity and Sparse Matrix techniques for large scale power systems- Optimal Ordering, Gaussian Elimination and Triangular factorization- LU Decomposition method, Node Elimination (Kron Reduction Technique).	8
2	Load Flow Studies: Newton - Raphson Method- Decoupled Newton Load Flow. Fast Decoupled Load Flow- AC DC load flow- simultaneous and sequential method - 3-Φ AC-DC Load flow concept, Problem formulation	8
3	FACTS devices in Load Flow - Power Flow Equation of FACTS devices -operating constraint- Implementation in Power Flow: Static Tap Changing, Phase Shifting (PS), Static Var Compensator (SVC), Thyristor Controlled Series Compensator (TCSC) , Unified Power Flow Controller (UPFC)	8
4	Optimal load flow in power Systems-constrained and unconstrained OPF -problem formulation-solution by Gradient method- Newtons method, Particle Swarm Optimization for OPF, Security and Environmental Constrained OPF(overview)	8
5	Z bus formulation with and without mutual coupling, Short circuit study of a large power system using Z-bus matrix. Unsymmetrical fault analysis using Z-bus- SLG Fault-LL Fault- DLG Fault	8

Course Plan

No	Topic	No. of Lectures
1	**MODULE: 1**	
1.1	Sparse matrix, Sparse Matrix techniques for large scale power systems, advantages and disadvantages of sparse matrix in power systems	1
1.2	Optimal Ordering	1
1.3	Gaussian Elimination	2
1.4	Triangular factorization- LU Decomposition method	2
1.5	Node Elimination Method (Kron Reduction Technique)	2
2	**MODULE: 2**	
2.1	Newton - Raphson Method of Load Flow	2
2.2	Decoupled Newton Load Flow, Fast Decoupled Load Flow	2
2.3	AC/DC load flow- simultaneous and sequential method	2
2.4	3-Φ Three phase Load Flow	2
3	**MODULE: 3**	
3.1	Incorporation of FACTS devices in Load Flow: Static Tap Changing, Phase Shifting (PS)	2
3.2	Static Var Compensator (SVC)- Power Flow Equation of SVC, Implementation of SVC in Power Flow	2
3.3	Thyristor Controlled Series Compensator (TCSC). Power Flow Equation and implementation in Power Flow	2
3.4	Unified Power Flow Controller (UPFC), Power Flow Equation and implementation in Power Flow	2
4	**MODULE: 4**	
4.1	Optimal load flow in power Systems- constrained and unconstrained OPF	1
4.2	Objective Function, Problem formulation	2
4.3	solution by Gradient method- Newtons method	2
4.4	Particle Swarm Optimization for OPF	2
4.5	Security and Environmental Constrained OPF	1
5	**MODULE: 5**	
5.1	Z bus formulation with and without mutual coupling	2
5.2	Short circuit study of a large power system using Z-bus matrix	2
5.3	Unsymmetrical fault analysis using Z-bus- SLG Fault-LL Fault- DLG Fault	4

Text Books:

1. Singh L P, "Advanced Power Systems Analysis and Dynamics", New Age Intl. Publishers, 1983.
2. Arrillaga J and Watson NR, "Computer Modelling of Electric Power Systems", John Wiley and sons,2001
3. Stagg and EL Abiad , "Computer Methods in Power system Analysis", McGraw Hill, 1968.
4. Kusic G L, "Computer Aided Power System Analysis", Prentice Hall, 1986.
5. Zhu J, "Optimization of power system operation", John Wiley & Sons

References:

1. Hadi Saadat, "Power System Analysis", McGraw Hill-1999.
2. Nagrath J J and Kothari D P, "Modern Power system Analysis", Tata McGraw Hill, 1980.
3. John J. Grainger and William D Stevenson, "Power System Analysis", McGraw Hill, 1994

4. Tinney WF and Meyer WS, “Solution of Large Sparse System by Ordered Triangular Factorization” IEEE Trans. on Automatic Control, Vol :8, pp:333-346, Aug 1973.

5. Zollenkopf K, “Bi-Factorization: Basic Computational Algorithm and Programming Techniques ; pp:75-96 ; Book on “Large Sparse Set of Linear Systems” Editor:J.K.Rerd, Academic Press, 1971.

6. Dommel HW, Tinney WF. Optimal power flow solutions. IEEE Trans. on Power Syst. 1968;87(10):1866–1876.

7. Das J. C ,”Load Flow Optimization and Optimal Power Flow”: 2 (Power Systems Handbook), CRC Press, 2017

8. K.R.Padiyar,” FACTS Controllers in Power Transmission and Distribution”, New Age International(P) Ltd., Publishers New Delhi, Reprint 2008

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 1	End Semester Examination
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

microcontrollers

(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- familiarization 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

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	

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	7

	copper at 1 kHz is 11.6 μΩ and the skin depth of copper at this frequency is 2mm	
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 and load current-Fourier spectrum- decoupling capacitors	2
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
221EEE001	POWER SYSTEMS OPERATION AND CONTROL	Program Elective 2	3	0	0	3

Preamble: The course comprises the concept of coordinating different generating units, along with computation of production costs, security controls, and corrective measures.

Prerequisites: Nil

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

CO 1	Examine the coordination and optimization of different generating stations.
CO 2	Analyse the types of power generation production cost programs
CO 3	Apply the various algorithms for power system state estimation
CO 4	Evaluate the security control and corrective methods
CO 5	Analyse the power system automation based on SCADA 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	1	3	3	2	1	-
CO 2	3	1	3	3	2	1	-
CO 3	3	1	3	3	2	1	-
CO 4	3	1	3	3	2	1	-
CO 5	3	1	3	3	2	1	-

Assessment Pattern

Bloom's Category	Continuous Assessment Tests	End Semester Examination
	1	
Remember		
Understand	20	20
Apply	20	40
Analyse	40	40
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/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: 2**

Reg No:________________
Name:__________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 221EEE001

Course name: POWER SYSTEMS OPERATION AND CONTROL

Max Marks: 60 **Duration: 2.5 Hours**

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

1) Explain the characteristics of hydro and thermal generation units

2) Explain the transmission losses in two generator system with suitable example

3) Describe probabilistic production cost model

4) What do you mean by external equivalencing?

5) Explain the functions of energy control centre with neat block diagram.

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

6) A hydro plant and a steam plant are to supply a constant load of 90MW for 1wk (168h). The unit characteristics are

Hydro plant: $q= 300+15P_H$ acre-ft/h

0 less than or equal to PH less than or equal to 100MW

Steam plant: $H_s=53.25+11.27P_s+0.0213P_s^2$

12.5 less than or equal to Ps less than or equal to 50MW

7) Explain the Formulation of optimal power flow solution by Newton's method.

8) Compute the production cost for a 3unit system without considering outages using load duration curve method. The energy is 43680 MWHr. The generation data is as follows

Unit No	Maximum Rating(kW)	Input Qutput Characteristics (R/Hr)	Full forced outage rate (pu)
1	60	60+ 3P1	0.2
2	50	70+3.5P2	0.1
3	20	80+4 P3	0.1

The load data is as follows

Load level (x MW)	Duration (Hrs)
30	134.4
50	134.4
70	134.4
80	168.0
100	100.8

9) Explain static state estimation using line only algorithm.

10) Explain weighted least square form of solution in state estimation.

11) Write short note on Preventive, Emergency and Restorative control

12) Explain the different levels of SCADA with neat diagram.

Syllabus

No	Power System Operation and Control	Contact hours
1	**Characteristics of power generation units**, Hydro thermal co-ordination- Problem definition and mathematical model of long- and short-term problems. Dynamic programming – Hydro thermal system with pumped hydro units – Solution of hydro thermal scheduling using Linear programming.	9
2	**System optimization** - strategy for two generator system – generalized strategies – effect of Transmission losses - Sensitivity of the objective function- Formulation of optimal power flow solution by Gradient method-Newton's method	7
3	**Production cost programs**: -Uses and types of production cost programs, probabilistic production cost programs. Sample computation -No forced outages – Forced outages included – interchange of power and energy and its types.	8
4	**State estimation**: Least square estimation – Basic solution. Sequential form of solution. Static State estimation of power system by different algorithms – Tracking state estimation of power system. Computer consideration – External equivalencing – Treatment of bad data.	8
5	**Power system security**: - System operating states by security control functions – Monitoring, evaluation of system state by contingency analysis – Corrective controls (preventive, emergency, and restorative) – Islanding scheme. **SCADA system: -** Energy control centre – Various levels – National – Regional and state level	8

Course Plan

No	Topic	No. of Lectures
1	**MODULE: 1 - Power generation units**	
1.1	Characteristics of power generation units	1
1.2	Hydro thermal co-ordination- Problem definition and mathematical model of long and short-term problems.	4
1.3	Dynamic programming	1
1.4	Hydro thermal system with pumped hydro units	1
1.5	Solution of hydro thermal scheduling using Linear programming	2
2	**MODULE: 2 - System optimization**	
2.1	Strategy for two generator system, generalized strategies, effect of Transmission losses	3
2.2	Sensitivity of the objective function- Formulation of optimal power flow solution by Gradient method	2
2.3	Newton's method	2
3	**MODULE: 3 - Production cost programs**:	
3.1	Uses and types of production cost programs	1
3.2	Probabilistic production cost programs	2
3.3	Sample computation -No forced outages – Forced outages	3

	included	
3.4	Interchange of power and energy and its types.	2
4	**MODULE: 4 - State estimation**	
4.1	Least square estimation – Basic solution, Sequential form of solution	2
4.2	Static State estimation of power system by different algorithms – Tracking state estimation of power system	3
4.3	Computer consideration – External equivalencing – Treatment of bad data	3
5	**MODULE: 5 - Power system security & SCADA system**	
5.1	System operating states by security control functions – Monitoring, evaluation of system state by contingency analysis	2
5.2	Corrective controls (preventive, emergency, and restorative) – Islanding scheme.	3
5.3	SCADA system: - Energy control centre – Various levels – National – Regional and state level	3

Reference Books

1. Allen J Wood, Bruce F Wollenberg, “Power Generation, Operation and Control”, John Wiley& Sons, New York, II Edition, 1984.
2. S Sivanagaraju, G Sreenivasan, “Power System Operation and Control”, Pearson Education India, 2009
3. Mahalanabis AK, Kothari DP and Ahson SI, “Computer Aided Power System Analysis and Control”, McGraw Hill Publishing Ltd., 1984.
4. Kundur P, “Power System Stability and Control”, McGraw Hill, 2006
5. http://nptel.ac.in/courses/108101040/by Dr.A M Kulkarni (IIT Bombay)

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221LEE100	ADVANCED POWER ELECTRONICS LAB	Laboratory 1	0	0	2	1

Preamble: To impart the practical knowledge about various power electronic circuits and its applications

Prerequisite: Fundamentals of power electronics course

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

CO 1	Demonstrate the practical knowledge on design and development of power electronic converters and drives
CO 2	Solve engineering problems related to power converters to provide feasible solutions
CO 3	Examine the performance of various power electronic converters in open and closed loop through any simulation software like MATLAB, PROTEUS, SCILAB etc.
CO 4	Analyse the experiment efficiently as an individual and as a member in the team to solve various problems
CO 5	Build laboratory reports as a document that clearly communicate experimental information

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	3	3	3	2	1
CO 2	3	1	3	3	3	2	1
CO 3	3	1	3	3	3	2	1
CO 4	2	2	3	3	2	3	2
CO 5	1	3	2	1	1	3	2

Assessment Pattern

The laboratory courses will be having only Continuous Internal Evaluation and carries 100 marks.

Continuous Internal Evaluation Pattern: 100 Marks

Regular performance evaluation in the laboratory (Output and Record) : 40%
Regular class viva voce : 20%
Final assessment : 40%

Final assessment shall be done by two examiners; one examiner will be a senior faculty from the same department assigned by the HOD

Final Assessment Mark Split up will be as follows:

Preliminary work - 30%
Performance - 30%
Results - 20%
Viva - 20%

List of simulation and Hardware Experiments- Obtain relevant waveforms and infer the result

Mandatory experiment

PCB design and fabrication of any dc-dc converter using standard software tool

Hardware Experiments (minimum five experiments)

1. Analog and/or digital gate driver for MOSFETS/ IGBTs using optocoupler isolation
2. Grid synchronization and firing circuit for SCR using digital and/or analog ICs
3. Speed control of chopper fed DC motor drive in continuous conduction mode
4. High frequency inductor/Transformer design
5. Regulated linear power supply with over current protection using OP-amp and power transistors and study/design the heat sink requirement
6. Open /closed loop control of dc-dc converters (Buck, Boost and Buck-Boost converter) using discrete ICs like TL494/SG3525/UC3842, Power loss computation, Selection of heat sinks
7. Open loop control of Flyback converter
8. Single Phase Semi-converter with R-L load for continuous / discontinuous conduction modes
9. Half bridge square wave inverter feeding RL load
10. Single-phase Sine triangle PWM/SVPWM inverter feeding RL load

Simulation (minimum 5 experiments)

1. Single phase and three phase full and half converter using RL and RLE loads
2. Single phase and three phase inverter with square wave, sine triangle PWM and SVPWM with RL load
3. Analog and/or digital gate driver for MOSFETS/ IGBTs using optocoupler isolation
4. Grid synchronization and firing circuit for SCR using digital and/or analog ICs
5. Open loop control of forward and pushpull converters
6. Open loop control of CUK and Sepic/half bridge and full bridge dc-dc converters
7. Speed control of chopper fed DC motor drive in continuous and discontinuous conduction mode
8. Zero Current switching for any resonant switch DC-DC converters
9. Zero Voltage Switching for any resonant switch DC-DC converter
10. Design, state variable model, bode plot , compensator, stability and closed control for a second order DC- DC converter.