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

Text book:

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

References:

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

Syllabus

Module I

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

Module II

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

Module III

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

Module IV

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

Module V

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

Course Plan

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

1.4	Linear Independence	2
1.5	Basis and Dimension	2
2	Linear Transformations	
2.1	Space of Linear Transformations	2
2.2	Matrix representation of linear transformations	3
2.3	Change of Basis and Similarity	3
3	Solutions to Linear System of Equations	
3.1	Rectangular Systems and Echelon Forms	2
3.2	Homogeneous and Non homogeneous systems	2
3.3	Eigenvalues, Eigenvectors, Eigenspaces	2
3.4	Diagonalizability	2
4	Linear Systems	
4.1	Solutions to LTI and LTV Systems	2
4.2	Analysis of stabilization by pole zero cancellation - 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 Riccati 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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11. S. Rajasekaran, G. A. Vijayalakshmi Pai, "; Neural Networks, Fuzzy Logic and Genetic Algorithm, Synthesis and Applications", PHI Learning Pvt. Ltd., 2017.
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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

PART A				
Answer all Questions. Each question carries 5 Marks				
Sl. No	Question	Marks	CO	BL
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: $R_s=0.12\Omega$, $R_r''=0.1\Omega$, $X_s=0.2\Omega$, $X_r''=0.15\Omega$. 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

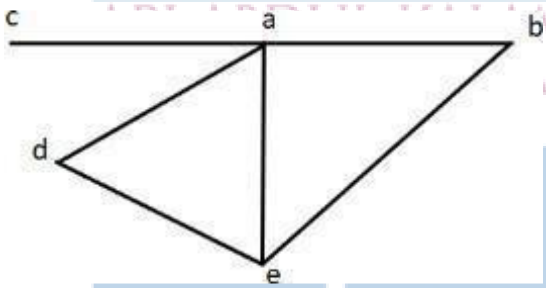
Course Code: 221EEE006

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.

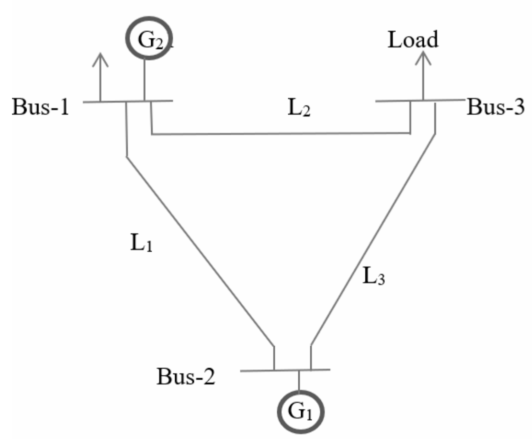


2. Compare Newton Raphson and Fast Decoupled Load flow algorithm
3. Explain the operation of TCSC in a power system.
4. Explain the salient features of Environmental Constrained OPF.
5. Build the Z bus for a three-phase short circuit fault in a power system.

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

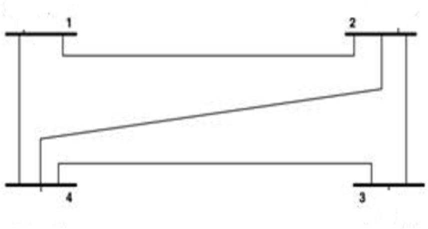


7. Obtain the load flow solution at the end of the first iteration of the power system shown in the figure. The data is provided in the Table. The solution is to be obtained for the following

cases

a) All buses except one are PV buses.

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

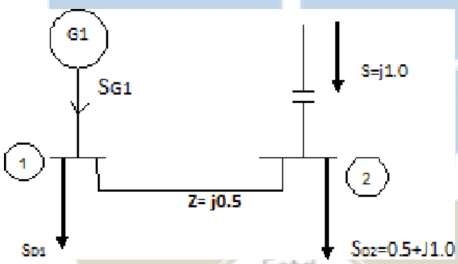


SB	EB	R(pu)	X(pu)
1	2	0.05	0.15
1	3	0.1	0.30
2	3	0.15	0.45
2	4	0.10	0.3
3	4	0.05	0.15

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.

$$Z_{bus}^{(1)} = Z_{bus}^{(2)} = j \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{bmatrix} 0.1437 & 0.1211 & 0.0789 & 0.0563 \\ 0.1211 & 0.1696 & 0.1104 & 0.0789 \\ 0.0789 & 0.1104 & 0.1696 & 0.1211 \\ 0.0563 & 0.0789 & 0.1211 & 0.1437 \end{bmatrix} \end{array}$$

$$Z_{bus}^{(0)} = j \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{bmatrix} 0.19 & 0 & 0 & 0 \\ 0 & 0.08 & 0.08 & 0 \\ 0 & 0.08 & 0.58 & 0 \\ 0 & 0 & 0 & 0.19 \end{bmatrix} \end{array}$$

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

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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.

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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	End Semester Examination
	1	
Remember		
Understand		10
Apply	20	40
Analyse	40	40
Evaluate	20	10
Create	20	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:
Continuous Internal Evaluation: 40 marks

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

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

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

Model Question paper

QP CODE: **PAGES:**

Reg No:_______________

Name:___

____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 221EEE007

Course name: EMBEDDED CONTROLLERS FOR POWER CONVERTERS

Max Marks: 60

Duration: 2.5 Hours

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

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

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

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

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

5) Describe the PWM module of C28X microcontroller

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

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

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

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

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

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

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

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

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.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221RGE100	RESEARCH METHODOLOGY & IPR	General Course	2	0	0	2

Preamble:

This course introduces the strategies and methods related to scientific research. The students are also trained in the oral presentation with visual aids and writing technical thesis/reports/research papers. The salient aspects of publication and patenting along with the crucial role of ethics in research is discussed.

Course Outcomes

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

CO 1	Approach research projects with enthusiasm and creativity.
CO 2	Conduct literature survey and define research problem
CO 3	Adopt suitable methodologies for solution of the problem
CO 4	Deliver well-structured technical presentations and write technical reports.
CO 5	Publish/Patent research outcome.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	70 %
Analyse	30 %
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Course based task: 15 marks

Some sample course based tasks that can be performed by the student given below.

- *Conduct a group discussion based on the good practices in research.*
- *Conduct literature survey on a suitable research topic and prepare a report based on this.*

Seminar: 15 marks

Test paper: 10 marks

End Semester Examination Pattern:

Total Marks: 60

The examination will be conducted by the respective college with the question provided by the University. The examination will be for 150 minutes and contain two parts; Part A and Part B. Part A will contain 6 short answer questions with 1 question each from modules 1 to 4, and 2 questions from module 5. Each question carries 5 marks. Part B will contain only 1 question based on a research article from the respective discipline and carries 30 marks. The students are to answer the questions based on that research article.

Model Question paper

QP Code:		**Total Pages:**
Reg No.: _______________		**Name:** __________________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
FIRST SEMESTER M. TECH DEGREE EXAMINATION, Month & Year

Course Code: 221RGE100
Course Name: RESEARCH METHODOLOGY & IPR

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

PART A

		Answer all questions. Each question carries 5 marks	**Marks**
1		Discuss the salient recommendations for great research recommended by Richard Hamming in his famous talk "You and Your Research"	**30**
2		What are the characteristics of a good research question? Discuss with an example.	
3		Explain the difference between continuum, meso-scale and micro scale approaches for numerical simulation.	
4		Discuss any four rules of scientific writing.	
5		What are the requirements for patentability?	
6		What are the differences between copyright and trademark protection?	
		Read the given research paper and write a report that addresses the following issues **(The paper given can be specific to the discipline concerned**)	
7		What is the main research problem addressed?	**3**
8		Identify the type of research	**3**
9		Discuss the short comings in literature review if any?	**6**
10		Discuss appropriateness of the methodology used for the study	**6**
11		Discuss the significance of the study and summarize the important results and contributions by the authors	**6**
12		Identify limitations of the article if any.	**6**

Syllabus and Course Plan

No	Topic	No. of Lectures
1	**Introduction**	
1.1	Meaning and significance of research, Skills, habits and attitudes for research, Types of research,	1
1.2	Characteristics of good research, Research process	1
1.3	Motivation for research: Motivational talks on research: "You and Your Research"- Richard Hamming	1
1.4	Thinking skills: Levels and styles of thinking, common-sense and scientific thinking, examples, logical thinking, division into sub-problems, verbalization and awareness of scale.	1
1.5	Creativity: Some definitions, illustrations from day to day life, intelligence versus creativity, creative process, requirements for creativity	1
2	**Literature survey and Problem definition**	
2.1	Information gathering – reading, searching and documentation, types of literature.	1
2.2	Integration of research literature and identification of research gaps	1
2.3	Attributes and sources of research problems, problem formulation, Research question, multiple approaches to a problem	1
2.4	Problem solving strategies – reformulation or rephrasing, techniques of representation, Importance of graphical representation, examples.	1
2.5	Analytical and analogical reasoning, examples, Creative problem solving using Triz, Prescriptions for developing creativity and problem solving.	1
3	**Experimental and modelling skills**	
3.1	Scientific method, role of hypothesis in experiment, units and dimensions, dependent and independent variables, control in experiment	1
3.2	precision and accuracy, need for precision, definition, detection, estimation and reduction of random errors, statistical treatment of data, definition, detection and elimination of systematic errors,	1
3.3	Design of experiments, experimental logic, documentation	1

3.4	Types of models, stages in modelling, curve fitting, the role of approximations, problem representation, logical reasoning, mathematical skills.	1
3.5	Continuum/meso/micro scale approaches for numerical simulation, Two case studies illustrating experimental and modelling skills.	1
4	**Effective communication - oral and written**	
4.1	Examples illustrating the importance of effective communication, stages and dimensions of a communication process.	1
4.2	Oral communication –verbal and non-verbal, casual, formal and informal communication, interactive communication, listening, form, content and delivery, various contexts for speaking- conference, seminar etc.	1
4.3	Guidelines for preparation of good presentation slides.	1
4.4	Written communication – Rules of scientific writing, form, content and language, layout, typography and illustrations, nomenclature, reference and citation styles, contexts for writing – paper, thesis, reports etc. Tools for document preparation-LaTeX.	1
4.5	Common errors in typing and documentation	1
5	**Publication and Patents**	
5.1	Relative importance of various forms of publication, Choice of journal and reviewing process, Stages in the realization of a paper.	1
5.2	Research metrics-Journal level, Article level and Author level, Plagiarism and research ethics	1
5.3	Introduction to IPR, Concepts of IPR, Types of IPR	1
5.4	Common rules of IPR practices, Types and Features of IPR Agreement, Trademark	1
5.5	Patents- Concept, Objectives and benefits, features, Patent process – steps and procedures	2

Reference Books

1. E. M. Phillips and D. S. Pugh, "How to get a PhD - a handbook for PhD students and their supervisors", Viva books Pvt Ltd.
2. G. L. Squires, "Practical physics", Cambridge University Press
3. Antony Wilson, Jane Gregory, Steve Miller, Shirley Earl, Handbook of Science Communication, Overseas Press India Pvt Ltd, New Delhi, 1st edition 2005
4. C. R. Kothari, Research Methodology, New Age International, 2004
5. Panneerselvam, Research Methodology, Prentice Hall of India, New Delhi, 2012.

6. Leedy P. D., Practical Research: Planning and Design, McMillan Publishing Co.
7. Day R. A., How to Write and Publish a Scientific Paper, Cambridge University Press, 1989.
8. William Strunk Jr., Elements of Style, Fingerprint Publishing, 2020
9. Peter Medawar, 'Advice to Young Scientist', Alfred P. Sloan Foundation Series, 1979.
10. E. O. Wilson, Letters to a Young Scientist, Liveright, 2014.
11. R. Hamming, You and Your Research, 1986 Talk at Bell Labs.

SEMESTER II

Discipline: ELECTRICAL & ELECTRONICS

Stream: EE2 (Power Electronics and Power Systems, Power Electronics and Drives, Power Electronics, Power Electronics and Control, Electrical and Electronics Engineering)

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222TEE100	**Computational Techniques in Electrical Engineering**	**Discipline Core -2**	3	0	0	3

Preamble:

Numerical computational techniques are indispensable for computing applications in electrical engineering systems. This course is designed with the objective of providing a foundation to the theory behind numerical computation and optimization techniques in electrical engineering systems. This course will equip the students with a mathematical framework for numerical computation and optimization techniques necessary for various computing applications in engineering systems.

Course Outcomes: After completing the course the student will be able to

CO 1	Apply numerical techniques to find the roots of nonlinear equations and solution of system of linear equations.
CO 2	Apply numerical differentiation and integration for electrical engineering applications
CO 3	Apply and analyze numerical techniques for solution to differential equation of dynamical systems
CO 4	Formulate optimization problems and identify a suitable method to solve the same
CO 5	Solve optimization problems in Electrical Engineering using appropriate optimization techniques

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Micro project/Course based project : 20 marks
Course based task/Seminar/Quiz : 10 marks
Test paper, 1 no. : 10 marks
Test paper shall include minimum 80% of the syllabus.

The project shall be done individually. Group projects not permitted.

End Semester Examination Pattern: 60 marks

Part A: 5 numerical/short answer questions with 1 question from each module, (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.
Each question can carry 5 marks.

Part B: 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five.
Each question can carry 7 marks.

Model Question Paper

SLOT A

APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY
SECOND SEMESTER M.TECH DEGREE EXAMINATION
MONTH &YEAR

Course code: **222TEE100**

Course Name: **Computational Techniques in Electrical Engineering**

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

PART A

Answer all Questions. Each question carries 5 Marks

1 What is condition number of a matrix. Use condition number to check whether the following matrix is ill-conditioned.

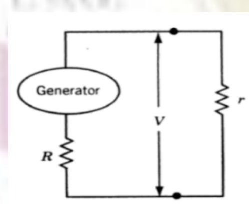
$$A = \begin{bmatrix} 1 & 1/2 & 1/3 \\ 1/2 & 1/3 & 1/4 \\ 1/3 & 1/4 & 1/5 \end{bmatrix}$$

2 Given the points $(0,0), \left(\frac{\pi}{2}, 1\right), (\pi, 0)$ satisfying the function $y = sin\ sin\ x\ (0 \leq x \leq \pi)$, determine the value of $y(\frac{\pi}{6})$ using the cubic spline approximation.

3 Solve the boundary value problem defined below using finite difference method. Compare the solution obtained at y(0.5) with the exact value for h=0.5 and h=0.25.

$$y'' - y = 0, \ \ y(0) = 0, y(1) = 1$$

4 An electric generator has an internal resistance of R ohms and develops an open circuit voltage of V volts. Find the value of the load resistance r for which power delivered by the generator will be a maximum. *(Represent the problem as an optimization problem and solve for maximum power.)*



Electric generator with load

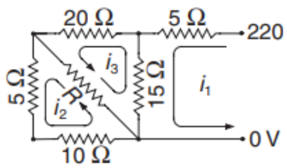
5 State the necessary and sufficient condition for existence of maximum or minimum for a multivariable objective function with constraints.

PART B

Answer any 5 Questions. Each question carries 7 Marks

6 The electrical network shown can be viewed as consisting of three loops. Apply Kirchoff's law to each loop yields and formulate the system as a classical linear algebraic

system. Compute the loop currents i_1, i_2 and i_3 using LU factorization method, for $R = 10\ \Omega$.



7 Find the zero of y(x) from the following data:

x	0	0.5	1	1.5	2	2.5	3
y	1.8421	2.4694	2.4921	1.9047	0.8509	−0.4112	−1.5727

Use Lagrange's interpolation over (a) three; and (b) four nearest-neighbor data points.

8 A second order system is defined by:

$$y'' = -\frac{19}{4}y - 10y', \quad y(0) = -9, y'(0) = 0$$

a. Find the analytical solution for the above system using the eigenvalues of the system

b. Show from (a) that the system is moderately stiff and estimate $\boldsymbol{h_{max}}$, the largest value of $\boldsymbol{h}$ for which the Runge–Kutta method would be stable.

c. Confirm the estimate by computing y(1) with h ≈ hmax/2 and h ≈ 2 hmax.

9 Faraday's law characterizes the voltage drop across an inductor as $V_L = L\frac{di}{dt}$, where V_L is the voltage drop (V), $\boldsymbol{L}$ is the inductance (in Henrys (H)), $\boldsymbol{i}$ is the current (in Amps), and $\boldsymbol{t}$ is the time (in secs). Determine the voltage drop as a function of time from the following data for an inductance of *4 H*.

Time, t (secs)	0	0.1	0.2	0.3	0.5	0.7
Current, i (Amps)	0	0.1	0.32	0.56	0.84	2.0

10 Is this a linear or nonlinear programming problem?
Maximize $Z = 3x_1^2 - 2x_2$, subject to the constraints:

$$2x_1 + x_2 = 4$$
$$x_1^2 + x_2^2 \leq 40$$
$$x_1, x_2 \geq 0 \quad \text{and are integers.}$$

Solve this problem by a suitable classical method.

11 Minimize $f(x_1, x_2) = x_1 - x_2 + 2x_1^2 + 2x_1x_2 + x_2^2$ from the starting point $X_1 = \{0, 0\}$ using Powell's method.

12 Minimize the function given below using Univariate method method taking $X_1 = \{1, 1\}$ as the starting point.

$$f(x_1, x_2) = 2x_1^2 - x_1x_2 + 3x_2^2$$

SYLLABUS

Module 1

Systems of Linear Algebraic Equations*:* Uniqueness of Solution, Ill conditioning and norms**;** Methods of Solution: Gaussian elimination – LU factorization – Matrix inversion – Gauss-Seidel iteration – least squares method**;** Eigenvalue problems - Power method for eigenvalues – Tridiagonalization and QR factorization

Module 2

Interpolation and Curve Fitting*:* Lagrange's Method, Newton's Method, Cubic Spline**;** Least-Squares Fit, Weighting of Data - Weighted linear regression**;** Roots of Equations: Newton–Raphson Method for systems of equations**;** Numerical differentiation - finite difference and first central difference approximations**;** Numerical integration - trapezoidal and Simpson's rule

Module 3

Solution to differential equations*:* Initial Value Problems - Taylor Series Method, Euler Method, Runge–Kutta Methods-Second-Order and Fourth Order; Stability and Stiffness;

Two-Point Boundary Value Problems*:* Shooting Method and finite difference method (Concept only)

Case Study*:* MATLAB/C/ Python programming for solution to differential equations. Two-Point Boundary Value Problems - Shooting Method (Demo/Assignment only)

Module 4

Optimization problem, Formulation of optimization problems - linear optimization - Review only.

Classical Optimization Techniques Single variable optimization, Multivariable optimization with equality constraints- Direct substitution, method of Lagrange multipliers, Multivariable optimization with equality constraints- Kuhn-Tucker conditions.

Module 5

Non-linear Programming - Unconstrained Optimization Techniques: Direct Search Methods: Random search methods, Grid search method, Univariate method, Hookes and Jeeves' method, Powell's method; Indirect Search Methods: Steepest descent method, Fletcher-Reeves method, Newton's method.
Nonlinear Programming - Constrained Optimization Techniques *(Concepts Only - not for evaluation in the end semester examination)***:** Direct search methods - Random search methods, Basic approach in methods of feasible directions, Zoutendijk's method of feasible directions,

Rosen's gradient projection method, Generalized Reduced gradient method, Sequential quadratic programming.

Recent developments in optimization techniques *(Concepts only - Not for evaluation in the end semester examination)*: Genetic Algorithm, Simulated Annealing, Neural Network based optimization, Particle Swarm Optimization, Ant colony Optimization.

Case studies- Power system optimization, Optimal control problem, Electrical machine design optimization, Optimal design of Power Electronic converter- **Assignment/Demo only**

References

1. Erwin Kreyszig, Advanced Engineering Mathematics 9th Edition, Wiley International Edition Press, Numerical Recipes for scientific computing.
2. Bhaskar Dasgupta, Applied Mathematical Methods, Pearson.
3. Arfken, Weber and Harris, Mathematical Methods for Physicists, A comprehensive guide, 7th Edition, Elsevier, 2013.
4. S.S. Sastry, Introductory methods of numerical analysis, Fifth edition, PHI.
5. Numerical methods in Engineering with MATLAB, Jaan Kiusalaas
6. Singiresu S Rao, *Engineering Optimization Theory and Practice*,5/e, John Wiley&Sons 2020.
7. Edwin K P Chong, Stanislaw H Zak, *An introduction to Optimization*, 2e, Wiley India.
8. Optimization in Electrical Engineering, Mohammad Fathi, Hassan Bevrani, Springer

COURSE PLAN

No	Topic	No. of Lectures
1	***Systems of Linear Algebraic Equations***	**9 hrs**
1.1	Uniqueness of Solution, Ill conditioning and norms	1
1.2	Methods of Solution: Gaussian elimination – LU factorization – Matrix inversion	3
1.3	Gauss-Seidel iteration – least squares method	2
1.4	Eigenvalue problems - Power method for eigenvalues – Tridiagonalization and QR factorization	3
2	***Interpolation and Curve Fitting***	**8 hrs**
2.1	Lagrange's Method, Newton's Method, Cubic Spline**;** Least-Squares Fit	3
2.2	Weighting of Data - Weighted linear regression	1

2.3	Roots of Equations: Newton–Raphson Method for systems of equations	1
2.4	Numerical differentiation - finite difference and first central difference approximations	2
2.5	Numerical integration - trapezoidal and Simpson's rule	1
3	***Solution to differential equations***	**7 hrs**
3.1	Initial Value Problems - Taylor Series Method	1
3.2	Euler Method	1
3.3	Runge–Kutta Methods - Second-Order and Fourth Order	2
3.4	Stability and Stiffness.	1
3.5	*Two-Point Boundary Value Problems:* Shooting Method and finite difference method (Concept only) *Case Study:* Two-Point Boundary Value Problems - Shooting Method (Demo/Assignment only)	2
4	***Formulation of Optimization problems and its solutions using classical methods***	**7 hrs**
4.1	Optimization problem, Formulation of optimization problems - linear optimization - Review only.	1
4.2	Constrained Linear Optimization- Single variable optimization	1
4.3	Multivariable optimization - Direct substitution	1
4.4	Method of Lagrange multiplier, Necessary and sufficient conditions - Problems	2
4.5	Equality and inequality constraints, Kuhn -Tucker conditions (*both linear and nonlinear)* – Problems	2
5	***Nonlinear - Unconstrained and constrained Optimization Techniques***	**9 hrs**
5.1	Nonlinear Optimization problem - Unconstrained and Constrained problems	1
5.2	Unconstrained Problems: Direct search methods - Random search-pattern search - Grid Search methods. *(Concepts only for Constrained Optimization.)*	2

5.3	Unconstrained - Univariate method, Hookes and Jeeves' method, Powell's method.	2
5.4	Indirect search methods: Descent Methods-Steepest descent, conjugate gradient, Fletcher- Reeves method.	2
5.5	*(Constrained Optimization - Concepts only - Not for evaluation)* Zoutendijk's method of feasible directions, Rosen's gradient projection method, Generalized Reduced gradient method, Sequential quadratic programming.	2

222TEE001	ADVANCED ELECTRIC DRIVES	CATEGORY	L	T	P	CREDIT
		Program core	3	0	0	3

Preamble:

This course focuses on vector control schemes which offer good dynamic performance when compared to classical scalar control schemes. Dynamic modelling and performance analysis of advanced drive schemes for induction machines, PMSM and BLDC motors are also covered in the syllabus. The concepts studied in the course will also be useful in other related applications such as EV battery chargers, FACTS, and custom power devices. After successful completion of the course, the students will be able to apply the control schemes for the control of Induction motors, permanent magnet synchronous motors, BLDC motors, front end rectifiers etc. 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 dynamic modelling of different types of Electrical Machines
CO 2	Analyse speed control schemes with good dynamic performance
CO 3	Select suitable power converters
CO 4	Compare the performance of different speed control schemes
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:
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.

Syllabus

Module I (8 hrs) [1,2,5]

Introduction to high performance drives- Equivalent circuit representation of magnetically coupled circuits- Air gap MMF due to sinusoidal winding distribution- Space vector representation- Dynamic modelling of induction machines – 3-phase to 2-phase transformation- Power equivalence- Generalized model in arbitrary reference frame– electromagnetic torque – Stator reference frame, rotor reference frame and synchronously rotating reference frame models- dynamic and steady state equivalent circuits

Module II (8 hrs) [2,3,4]

Principle of vector or field oriented control – Comparison with separately excited dc motor- direct rotor flux oriented vector control – Selection of Flux level- Estimation of rotor flux and torque– Indirect rotor flux oriented vector control scheme- Flux weakening- Parameter sensitivity - implementation with current regulated VSI and PWM VSI- Speed controller design- Self Commissioning of drives

Module III (8 hrs) [2,3,4]

Stator flux oriented vector control- decoupling requirements- implementation of with current source and current regulated inverters- Parameter sensitivity in stator flux orientation- Selection of Flux level - Flux weakening - comparison with dc motor torque capability curves- Sensor less vector control- Direct torque control (DTC) of induction motor – control strategy - comparison of DTC and FOC- Vector control of line side PWM rectifier

Module IV (8 hrs) [3,4,6]

Permanent magnet synchronous machine (PMSM) drives – types of permanent magnets and characteristics– operating point and air gap line- radial and parallel magnetization- Halbach arrays- SPM and IPM machines- Modelling of PMSM- Vector control strategies – constant torque-angle control- unity power factor control- maximum torque per ampere- constant mutual flux linkage control- flux weakening

Module V (8 hrs) [3,4,6]

PM brushless (BLDC) DC motor – modeling of BLDC motor – operating principle- Speed-Torque characteristics- Torque Pulsation- Six switch converter- Split supply Converter- Drive scheme without field weakening- Current and Speed Control- Regenerative braking- Extended speed of operation - Sensorless control- back emf detection method

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).

No	Topic	No. of Lectures
1	Introduction to high performance drives- Equivalent circuit representation of magnetically coupled circuits- Air gap MMF due to sinusoidal winding distribution- Space vector representation- Dynamic modelling of induction machines – 3-phase to 2-phase transformation- Power equivalence- Generalized model in arbitrary reference frame– electromagnetic torque – Stator reference frame, rotor reference frame and synchronously rotating reference frame models- dynamic and steady state equivalent circuits [1,2,5]	
1.1	Introduction to high performance drives	1
1.2	Equivalent circuit representation of magnetically coupled circuits	1
1.3	Air gap MMF due to sinusoidal winding distribution	1
1.4	Space vector representation- Dynamic modelling of induction machines – 3-phase to 2-phase transformation	1
1.5	Power equivalence- Generalized model in arbitrary reference frame– electromagnetic torque	1
1.6	Stator reference frame, rotor reference frame and synchronously rotating reference frame models	2
1.7	Dynamic and steady state equivalent circuits	1
2	Principle of vector or field oriented control – Comparison with separately excited dc motor- direct rotor flux oriented vector control – Selection of Flux level- Estimation of rotor flux and torque– Indirect rotor flux oriented vector control scheme- Flux weakening- Parameter sensitivity - implementation with current regulated VSI and PWM VSI- Speed controller design- Self Commissioning of drive [2,3,4]	

2.1	Principle of vector or field oriented control – Comparison with separately excited dc motor	1
2.2	Direct rotor flux oriented vector control	1
2.3	Selection of Flux level- Estimation of rotor flux and torque	1
2.4	Indirect rotor flux oriented vector control scheme	1
2.5	Implementation with current regulated VSI and PWM VSI	1
2.6	Flux weakening and Parameter sensitivity in rotor flux orientation	1
2.7	Speed controller design	1
2.8	Self Commissioning of drive	1
3	Stator flux oriented vector control- decoupling requirements- implementation of with current source and current regulated inverters- Parameter sensitivity in stator flux orientation- Selection of Flux level - Flux weakening - comparison with dc motor torque capability curves- Sensor less vector control- Direct torque control (DTC) of induction motor – control strategy - comparison of DTC and FOC- Vector control of line side PWM rectifier [2,3,4]	
3.1	Stator flux oriented vector control- decoupling requirements- implementation of with current source and current regulated inverters	1
3.2	Parameter sensitivity in stator flux orientation-	1
3.3	Selection of Flux level - Flux weakening	1
3.4	Comparison with dc motor torque capability curves	1

3.5	Sensor less vector control-	1
3.6	Direct torque control (DTC) of induction motor – control strategy	1
3.7	Comparison of DTC and FOC	1
3.8	Vector control of line side PWM rectifier	1
4	Permanent magnet synchronous machine (PMSM) drives – types of permanent magnets and characteristics– operating point and air gap line- radial and parallel magnetization- Halbach arrays- SPM and IPM machines- Modelling of PMSM- Vector control strategies – constant torque-angle control- unity power factor control- constant mutual flux linkage control- flux weakening [3,4,6]	
4.1	Types of permanent magnets and characteristics– operating point and air gap line- radial and parallel magnetization- Halbach arrays	2
4.2	SPM and IPM machines	1
4.3	Modelling of PMSM	1
4.4	Vector control strategies – constant torque-angle control	1
4.5	Unity power factor control- constant mutual flux linkage control-	2
4.6	Flux weakening	1
5	PM brushless (BLDC) DC motor – modeling of BLDC motor – operating principle- Speed-Torque characteristics- Torque Pulsation- Six switch converter- Split supply Converter- Drive scheme without field weakening- Current and Speed Control- Regenerative braking- Extended speed of operation - Sensorless control- back emf detection method [3,4,6]	

5.1	PM brushless (BLDC) DC motor –Introduction	1
5.2	Modeling of BLDC motor – operating principle	1
5.3	Speed-Torque characteristics	1
5.4	Torque Pulsation	1
5.5	Six switch converter- Split supply Converter	1
5.6	Drive scheme without field weakening- Current and Speed Control	1
5.7	Regenerative braking- Extended speed of operation	1
5.8	Sensorless control- back emf detection method	1

References

1. P. C. Krause, Wasynczuk and Sudhoff, "Analysis of Electric Machinery and Drive Systems", Wiley, 2004

2. A.M. Trzynadlowski, "Field orientation Principle in the control of Induction Motors, Kluwer, 1994

3. R. Krishnan, "Electric Motor Drives", PHI, 2007

4. B. K. Bose, "Modern Power Electronics and AC Drives", PHI, 2006

5. Ned Mohan, "Advanced Electric Drives- Analysis, Control and Modelling", John Wiley, 2014

6. R. Krishnan, "Permanent Magnet Synchronous and Brushless dc drives", CRC Press, 2010

Model Question Paper

	Model Question paper	Slot **B**
APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY		
FIRST SEMESTER M.TECH DEGREE EXAMINATION MONTH & YEAR		
Course code: 222TEE001	Course Name: ADVANCED ELECTRIC DRIVES	
Max. Marks: 60		Duration: 2.5 Hours

PART A				
Answer all Questions. Each question carries 5 Marks				
Sl. No	Question	Marks	CO	BL
1	Show that power invariance is maintained in the transformation of three phase to two phase voltages and currents	5	1	2
2	Derive the time constants associated with the flux producing channel in an indirect vectorcontrolled induction motor drive and compare with that of separately excited dc motor	5	2	3
3	Explain the operation of any suitable drive scheme for BLDC motor during forward motoring and regenerative braking	5	5	3
4	Explain parameter sensitivity issues and the effects of parameter sensitivity in stator flux oriented vector control scheme	5	3	1
5	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
PART –B				
(Answer any five questions, each question carries 7 marks)				
6	(a) What do you mean by sinusoidal winding distribution? A sinusoidal distributed winding carries a three-phase current expressed as ia=10cos(314t), ib=10cos(314t-120˚) and ic=10cos(314t-240˚). Determine	3	1	4

	the resultant voltage space vector at ωt=0°, ωt=30°, ωt=60° in the stator reference frame and draw the locus of the voltage space vector for one full cycle.			
	(b) Derive the dynamic model of an induction motor in the stator reference frame and draw the dynamic equivalent circuit	4	1	3
7	(a) (i) Explain the basic concept of vector control schemes. How is it different from scalar control schemes? (ii) With space vector diagram and block schematic, explain indirect rotor flux oriented vector control scheme	3	2	1
	(b) An induction motor has the following parameters: 5hp, 200V, 4 pole, 3-phase, 50Hz, Y connected, Rs=0.277 Ω, Rr=0.183Ω, Lm=0.0538H, Ls=0.0553H, Lr=0.056H. The motor is supplied with its rated and balanced voltages. Find the direct and quadrature axis steady state voltages and currents when the speed of the motor is 1350 rpm. Use synchronous reference frame model	4	2	5
8	(a) With a space vector diagram and block schematic, explain stator flux oriented vector control scheme. Mention the limitations. Compare the performance with rotor flux oriented vector control schemes	3	3	1
	(b)Explain how the developed torque can be controlled directly by controlling the angle between stator flux linkage and rotor flux linkage. Assuming that the stator flux vector is at 85° in the stationary plane, prepare a suitable voltage-space-vector selection table for direct torque control (DTC). Compare the performance with vector control schemes	4	3	4
9	(a) Compare SPM and IPM machines in terms of construction, operating characteristics and speed control	3	4	1
	(b) Develop an equivalent circuit model of PMSM	4	4	3
10	Explain how back emf voltage can be used for sensorless control of BLDC motor	3	5	1
	(b) Explain constant torque-angle control in PMSM	4	5	2
11	(a) Explain the vector control of line side PWM rectifier	3	4	1
	(b) Compare and contrast vector control schemes with PWM voltage source inverter and hysteresis current controlled VSI for high power applications	4	4	2
12	(a) What do you mean by sensorless drive? Explain any one sensor less vector control scheme for IM and compare the performance with indirect rotor flux orientation	3	1	3

	(b) What do you mean by self commissioning of drives? Explain	4	2	1

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE100	Facts And Custom Power Devices	Program Elective 3	**3**	**0**	**0**	**3**

Preamble: To familiarize the students with the transmission challenges of modern electrical power systems and the need of FACTS controllers. The course presents the basic concept of Flexible AC Transmission Systems (FACTS) that enhances power system stability and effectively increases the transmission capacity. After the completion of the course, students will develop a deeper knowledge on various control and implementation techniques of FACTS devices and the Custom power devices.

Course Outcomes:

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

CO 1	Use FACT controllers for various power quality issues.
CO 2	Solve the reactive power problems in power systems using FACTS devices.
CO 3	Have a full understanding of the presence of harmonics and the different power quality conditions.
CO 4	Learn to Optimize the performance of power system using combination of FACTS controllers
CO 5	Develop and promote research interests in controllers for reducing consumer end problems in power 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	3	3	3	2	1
CO 2	3	2	3	3	3	2	1
CO 3	3	2	3	3	3	2	1
CO 4	3	2	3	3	3	2	1
CO 5	3	2	3	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:

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 transmission problems and emergence of facts solutions:** Fundamentals of ac power transmission, transmission problems, power flow, controllable parameters. Power quality – basic concept. Voltage regulation and reactive power flow control- Needs, emergence of FACTS- Types of FACTS controllers-Advantages and disadvantages - shunt compensation - Series compensation -Phase angle control –basic relationships	8
II	**Shunt compensators:** Objectives of shunt compensation-shunt SVC-TCR – TSC – Effect of initial charge - combined TCR and TSC configurations – characteristics - Analysis -Elimination of harmonics – Control schemes - Static synchronous compensator (STATCOM) configuration and control, comparison between SVC and STATCOM - Applications- case studies	9
III	**Series compensators**: Static series compensation –Objectives- GCSC – TSSC – TCSC characteristics – Basic Control Schemes - Sub synchronous characteristics- Basic NGH SSR Damper - Static Synchronous Series Compensator (SSSC): Principle of operation – Analysis and characteristics - control scheme.	8
IV	**Unified power flow controller (UPFC):** Principles of operation and characteristics, independent active and reactive power flow control, comparison of UPFC to the controlled series compensators, control structure and dynamic performance. Interline Power Flow Controller (IPFC) – Basic operating Principles and Characteristics and control schemes.	7

V	**Custom Power Devices:** Types – configuration – SSCL – SSCB – SSTS – compensation – Filters - Static voltage & phase angle regulator - TCVL- TCVR- TCBR -Distribution STATCOM – Dynamic Voltage Restorer – Unified Power Quality Conditioner – Application of D-STATCOM, DVR and UPQC- case studies	8

REFERENCES:

1. Song, Y.H and Allan. T. Johns, 'Flexible Ac Transmission Systems (FACTS); Institution of Electrical Engineers Press, London, 1999
2. Hingorani, L Gyugyi ``Concepts and Technology of Flexible Ac Transmission System', IEEE Press New Yourk, 2000 Isbn- 078033 4588.
3. K R Padiyar, "FACTS Controllers in Power Transmission and Distribution", New Age International Publishers, 2007
4. IEE Tutorials on 'Flexible Ac Transmission Systems' Published in Power Engineering Journal, IEE Press, 1995.
5. Miller, T J E "Reactive Power Control in Power Systems" John Wiley, 1982.
6. Padiyar K.R. "Facts Controllers in Power Transmission and Distribution", New Age International Publishers, June 2007.
7. S Denesh Kumar, 'Flexible AC Transmission System', Anuradha Publishers, 2013.
8. R Sreeram Kumar, 'Flexible AC Transmission System', Institution of Engineers.
9. Abhijit Chakrabarti,'Power System Analysis, Operation and Control', PHI.

Course Plan

No	Topic	No. of Lectures
1	**Power transmission problems and emergence of facts solutions:** Fundamentals of ac power transmission, transmission problems, power flow, controllable parameters. Power quality – basic concept. Voltage regulation and reactive power flow control- Needs, emergence of FACTS- Types of FACTS controllers-Advantages and disadvantages - shunt compensation - Series compensation -Phase angle control –basic relationships.	
1.1	**Power transmission problems and emergence of facts solutions:** Fundamentals of ac power transmission, transmission problems, power flow, controllable parameters.	2
1.2	Power quality – basic concept. Voltage regulation and reactive power flow control- Needs, emergence of FACTS	1
1.3	Types of FACTS controllers - Advantages and Disadvantages	1

1.4	shunt compensation	1
1.5	Series compensation	1
1.6	Phase angle control –basic relationships	2
2	**Shunt compensators:** Objectives of shunt compensation-shunt SVC-TCR – TSC – Effect of initial charge - combined TCR and TSC configurations – characteristics - Analysis -Elimination of harmonics – Control schemes - Static synchronous compensator (STATCOM) configuration and control, comparison between SVC and STATCOM - Applications- case studies	
2.1	**Shunt compensators:** Objectives of shunt compensation-shunt SVC-TCR – TSC	2
2.2	Effect of initial charge	1
2.3	Combined TCR and TSC configurations – characteristics - Analysis	2
2.4	Elimination of harmonics	1
2.5	Static synchronous compensator (STATCOM) configuration and control	1
2.6	Comparison between SVC and STATCOM - Applications- case studies	2
3	**Series compensators**: Static series compensation –Objectives- GCSC – TSSC – TCSC characteristics – Basic Control Schemes - Sub synchronous characteristics- Basic NGH SSR Damper - Static Synchronous Series Compensator (SSSC): Principle of operation – Analysis and characteristics - control scheme.	
3.1	Static series compensation –Objectives- GCSC – TSSC – TCSC characteristics	3
3.2	Basic Control Schemes - Sub synchronous characteristics	2
3.3	Basic NGH SSR Damper	1
3.4	Static Synchronous Series Compensator (SSSC): Principle of operation – Analysis and characteristics - control scheme.	2
4	**Unified power flow controller (UPFC):** Principles of operation and characteristics, independent active and reactive power flow control, comparison of UPFC to the controlled series compensators, control structure and dynamic performance.	

	Interline Power Flow Controller (IPFC) – Basic operating Principles and Characteristics and control schemes.	
4.1	**Unified power flow controller (UPFC):** Principles of operation and characteristics, independent active and reactive power flow control	2
4.2	Comparison of UPFC to the controlled series compensators, control structure and dynamic performance.	2
4.3	Interline Power Flow Controller (IPFC) – Basic operating Principles and Characteristics and control schemes.	3
5	**Custom Power Devices:** Types – configuration – SSCL – SSCB – SSTS – compensation – Filters - Static voltage & phase angle regulator - TCVL- TCVR- TCBR -Distribution STATCOM – Dynamic Voltage Restorer – Unified Power Quality Conditioner – Application of D-STATCOM, DVR and UPQC- case studies	
5.1	**Custom Power Devices:** Types – configuration – SSCL – SSCB – SSTS – compensation - Filters	2
5.2	Static voltage & phase angle regulator - TCVL- TCVR- TCBR	2
5.3	Distribution STATCOM	1
5.3	Dynamic Voltage Restorer	1
5.4	Unified Power Quality Conditioner – Application of D-STATCOM, DVR and UPQC- case studies	2

Model Question paper

APJ Abdul Kalam Technological University

222EEE100– FACTS and Custom Power Devices

Time : 3 hrs. Max.Marks:60

PART A (5X5=25 marks)

1) What is power quality? Explain its significance in the power system.

2) Explain the working of TSR and compare it with TCR.

3) What is meant by Sub synchronous Resonance? How is it avoided in series compensation?

4) Explain the basic concept of UPFC control scheme.

5) With a neat diagram, explain the principle of operation of D-STATCOM.

PART B

Answer any 5 questions

6) What is the purpose of using FACTS devices in a power system? List the different types of FACTS controllers. (7 marks)

7) Explain the effect of initial charge of capacitor in TSC. (7 marks)

8) Explain the operation and characteristics of SSSC (7 marks)

9) Derive the expression for real and reactive power (P&Q) in UPFC and plot the variation with load angle. (7 marks)

10) Explain the characteristics and control scheme of IPFC. (7 marks)

11) What is the need of custom power devices in a power system? What are its advantages? (7 marks)

12) What are the objectives of a static voltage regulator? Explain the working principle. (7 marks)

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EE001	SOLAR AND WIND POWER CONVERSION SYSTEMS	PEC	3	0	0	3

Preamble: Solar and wind power conversion systems together take a lion's share in the whole of renewable energy conversion systems today. This course focuses on the selection, design and utilization of solar and wind power conversion systems. A basic course in Power Electronics is a desirable prerequisite for the course.

Course Outcomes:

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

CO 1	Get a solid foundation of solar and wind energy conversion systems
CO 2	Analysis and design of standalone and grid connected solar PV systems
CO 3	Design various MPPT algorithms of solar PV in detail
CO 4	Analysis and design of grid connected wind conversion systems

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	Continuous Evaluation/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

QP CODE: **PAGES:**

Reg No:______________ **Name:________________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 222EE001

Course name: SOLAR AND WIND POWER CONVERSION SYSTEMS

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

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

1) Plot the spectral distribution of extra terrestrial and terrestrial solar radiation and explain

2) Discuss about important battery performance parameters of a lead-acid battery to be used in a solar PV stand alone inverter system

3) At certain irradiation and ambient temperature, a solar panel has its maximum power point at a panel voltage of 18.5V and current of 4.2A. A boost converter is used for MPPT, delivering power to a 10Ω resistive load. Determine the duty cycle needed for the converter for operation at MPPT at this operating condition

4) Explain the Power Vs rotor speed characteristics of a typical wind turbine for a fixed pitch wind turbine. Also explain how maximum wind power can be tracked

5) Explain the significance of Lift and Drag coefficients of wind air-foils

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

6) Explain the principle of operation of PN junction solar cell and discuss any realistic equivalent circuit. Also discuss the methods used to improve the solar cell efficiency

7) Calculate the efficiency and peak power of Si solar cell operating at 27 deg.C, with short circuit current of 2.2 A and operating under standard illumination of 1000W/m2. The area of the solar cell is 100 cm^2. If the operating temperature of the solar cell increases to 35 deg. C, Calculate the efficiency. (Assume FF = 0.75, $I_0 = 10^{-12}$ A)

8) Explain in detail the series-parallel mismatch in PV module configuration

and possible remedies

9) Design an Stand alone PV (SPV) system to be used at Cochin (9.9312° N, 76.2673° E) for which the load requirements are given in the table. The system should allow the use of non-sunshine hours for ONE day. The operating hours and power rating of these loads are also given.

Load	**Rating (watts)**	**Hours/day**	**Quantity**
LED Bulb	9	5	3
TV	200	1	1
BLDC Fan	40	5	2
Computer	250	2	1

10) Explain the circuit configuration and operation of a permanent magnet synchronous generator based wind power plant

11) A wind turbine is operating with a tip speed ratio of 5. If the angle of attack is 6° and the wind speed is 10 m/s, determine the blade pitch angle at the tip of the blade

12) With necessary circuit schematics, explain variable speed induction generators with partial rated power converter topologies

Syllabus

No	**SOLAR AND WIND POWER CONVERSION SYSTEMS**	**Contact hours**
1	Solar Cells: Sun and earth- Basic characteristics of solar radiation- solar Cell characteristics- construction- generation of photo electricity- equivalent circuit- losses in solar cells, energy conversion efficiency, effect of variation of solar insolation and temperature on efficiency- types of solar PV- monocrystalline, polycrystalline and thin film- Performance and comparison	7
2	Solar PV modules - Series and parallel connection of cells - design and selection of PV module - partial shading of solar cells and modules- measurement of voltage and current- protection- batteries for PV systems- lead acid and lithium-ion batteries- characteristics - charging and discharging rate- protection	8
3	MPPT Algorithms: open circuit voltage and short circuit current- Perturb and Observe- Incremental conductance- Realisation of MPPT using dc-dc converters- buck, boost	9

	and buck-boost- comparison- single axis and dual axis tracking- System level design of standalone and grid connected systems- Inverter topologies - LCL filter- Net Metering- Isolation- grounding and protection- relevant IEEE standards	
4	Wind energy – energy in the wind – aerodynamics - rotor types – forces developed by blades - Aerodynamic models – braking systems – tower - control and monitoring system- design considerations- power curve - power speed characteristics	8
5	Choice of electrical generators - wind turbine generator systems- fixed speed induction generator- semi variable speed induction generator-variable speed induction generators with full and partial rated power converter topologies- performance analysis.	8

Course Plan

No	Topic	No. of Lectures
1	**MODULE:1**	
1.1	Sun and earth- Basic characteristics of solar radiation	1
1.2	Solar Cells: solar Cell characteristics- construction- generation of photo electricity- diode equivalent circuit	2
1.3	Losses in solar cells, energy conversion efficiency, effect of variation of solar insolation and temperature on efficiency	2
1.4	Types of solar PV- monocrystalline, polycrystalline and thin film- Performance and comparison	2
2	**MODULE:2**	
2.1	Solar PV modules - Series and parallel connection of cells - design and selection of PV module	2
2.2	Partial shading of solar cells and modules- measurement of voltage and current- protection	2
2.3	Batteries for PV systems- lead acid and lithium-ion batteries- characteristics - charging and discharging rate- protection	3
3	**MODULE:3**	
3.1	MPPT Algorithms: open circuit voltage and short circuit current	1
3.2	Perturb and Observe, Incremental conductance	1

3.3	Realisation of MPPT using dc-dc converters- buck, boost and buck-boost- comparison	2
3.4	Single axis and dual axis tracking	1
3.5	System level design of standalone and grid connected PV systems	1
3.6	Inverter topologies - LCL filter	1
3.7	Net Metering- Grounding and protection- relevant IEEE standards	2
4	**MODULE:4**	
4.1	Wind energy – energy in the wind, aerodynamics	1
4.2	Rotor types – forces developed by blades - Aerodynamic models – braking systems	3
4.3	Tower - control and monitoring system	1
4.4	Design considerations- power curve - power speed characteristics	3
5	**MODULE:5**	
5.1	Choice of electrical generators	1
5.2	Wind turbine generator systems- fixed speed induction generator- semi variable speed induction generator	3
5.3	Variable speed induction generators with full and partial rated power converter topologies- performance analysis.	4

References:

1. Chetan Singh Solanki, "Solar Photovoltaics-Fundamentals, Technologies and Applications", PHI Learning Pvt. Ltd., New Delhi, 2011

2. Anne Labouret and Michel Villoz, "Solar Photovoltaic Energy", IET, 2010

3. S.N. Bhadra, D. Kastha and S. Banerje, "Wind Electrical Systems", Oxford Uni Press, 2005.

4. Siegfried Heier, Rachel Waddington, "Grid Integration of Wind Energy Conversion Systems", Wiley, 2006,

5. John F.Walker & Jenkins. N , "Wind Energy Technology", John Wiley and sons, Chichester, UK, 1997.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE002	DISTRIBUTED GENERATION AND PROTECTION	Program Elective 3	3	0	0	3

Preamble: The penetration of renewable energy sources into the power system grid is increasing by leaps and bounds. The course will discuss the concept of distributed generation, analyse the impact of grid integration & power quality issues and the design of grid integration of DG sources with dc and ac microgrids.

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

CO 1	Review of energy sources and storage devices for distributed generation
CO 2	Analyze grounding and protection in distributed generation
CO 3	Design grid integration systems for dc and ac micro grids
CO 4	Analyze the power quality issues and control of power flow in dc/ ac microgrids/smart grids
CO 5	Analyze power converters and design current control and protection schemes for dc/ ac microgrids/smart grids

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 C**
APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY		
FIRST SEMESTER M.TECH DEGREE EXAMINATION MONTH & YEAR		
Course code: 222EEE002	Course Name: DISTRIBUTED GENERATION AND PROTECTION	
Max. Marks: 60		Duration: 2.5 Hours

	Part A (Answer all questions)	**5x5=25**
1	Explain the Architecture of Smart Grid System and compare with conventional utility grid	5
2	Explain any suitable method for frequency estimation in microgrid	5
3	Explain the need for grounding in DG, different grounding schemes and grounding considerations	5
4	Explain radial, loop and network distribution in DG	5
5	What is meant by Fault Ride-Through Capability of Distributed Generation in Microgrid? How can it be enhanced?	5
	Part B (Answer any five questions)	**7x5=35**
6	Explain any one active anti-islanding detection method in ac microgid	7
7	Explain (i) active load sharing (ii) droop control in DC microgrid and compare	7

8	Explain (i) the need for grounding in DG (ii) different grounding schemes and (iii) grounding considerations for DG	
8	Explain micro PMU and the use of wide area monitoring system in Smart Grid	7
10	Explain the selection and coordination of relays, reclosers, sectionalizers and fuses for the protection of a radial DG system	7
11	Explain a power converter suitable for plug-in EV charger to be used in an ac microgrid	7
12	Explain in detail any current control scheme with good dynamic performance in grid connected inverter	7

Syllabus

Module I (7 hrs)

Distributed generation (DG)- DG vs Traditional bulk power generation- Distributed Energy Resources (DER) in DG – Overview of wind power, solar PV, solar thermal- fuel cell, micro CHP and small hydro- basic properties and challenges as DG source- Requirement of energy storage- stabilization- Ride through- dispatchability- Energy storage elements in DG – batteries, ultracapacitors, flywheels, superconducting magnet energy storage

Module II (7 hrs)

Requirements for grid interconnection- IEEE 1547 standard- local electric power system (EPS), area EPS, point of common coupling (PCC)- bulk power system (Macrogrid), DER, planning of DGs – siting and sizing of DGs – limits on operational parameters- enter service- real and reactive power control requirements- response to area EPS abnormal conditions- voltage and frequency ride through requirements- Flicker limit- Total Rated-Current Distortion (TRD)- Grounding considerations

Module III (9 hours)

Fault analysis- types of faults- Overview of symmetrical components- sequence representation of distribution networks- fault analysis- overcurrent protection- coordination of relays, reclosers, and sectionalizers and fuses- solid state circuit breaker- digital overcurrent detection (directional)- blinding of protection- sympathetic tripping- Islanding- intentional and unintentional- islanding detection and anti-islanding protection- passive, active and communication based techniques- Case studies

Module-IV (9 hrs)

Concept and definition of Microgrid- typical structure and configuration of ac microgrid- modes of operation and control- grid connected and islanded mode- Power converter topologies and control schemes for power sharing- droop control- communication based control- grid interactive power converters- features - current control- phase locked loops (PLL) and frequency locked loops (FLL)- Interconnection to grid- current control- Filter design- passive and active damping- active load management, DG active and reactive power dispatch, control of transformer taps- radial, loop and network distribution- voltage regulation and system reconfiguration

Module-V (8 hrs)

DC microgrid- structure- grid connected and isolated modes of operation- overview of power electronic converters for DC microgrid - droop control- active load sharing- Hierarchical Control in DC microgrids

Introduction to smart grids- smart metering- smart grid communication infrastructure, wide area monitoring systems (WAMS)- micro phasor measurement unit (PMU)- power quality issues in smart grids, regulatory standards- Impact of plug in EV- smart grid economics, demand side management and demand response analysis of smart grid- Case studies

Syllabus and Course Plan

No	Topic	No. of Lectures
1	Distributed generation (DG)- DG vs Traditional bulk power generation- Distributed Energy Resources (DER) in DG – Overview of wind power, solar PV, solar thermal- fuel cell, micro CHP and small hydro- basic properties and challenges as DG source- Requirement of energy storage- stabilization- Ride through- dispatchability- Energy storage elements in DG – batteries, ultracapacitors, flywheels, superconducting magnet energy storage	
1.1	Distributed generation (DG)- DG vs Traditional bulk power generation- Distributed Energy Resources (DER) in DG –	2
1.2	Overview of wind power, solar PV, solar thermal- fuel cell, micro CHP and small hydro- basic properties and challenges as DG source-	2

1.3	Requirement of energy storage- stabilization- Ride through-dispatchability-	1
1.4	Energy storage elements in DG – batteries, ultracapacitors, flywheels, superconducting magnet energy storage	2
2	Requirements for grid interconnection- IEEE 1547 standard- local electric power system (EPS), area EPS, point of common coupling (PCC)- bulk power system (Macrogrid), planning of DGs – siting and sizing of DGs – limits on operational parameters- enter service- real and reactive power control requirements- response to area EPS abnormal conditions- voltage and frequency ride through requirements- Flicker limit- Total Rated-Current Distortion (TRD)- Grounding considerations	
2.1	Requirements for grid interconnection- IEEE 1547 standard- local electric power system (EPS), area EPS, point of common coupling (PCC)- bulk power system (Macrogrid)	2
2.2	Planning of DGs – siting and sizing of DGs – limits on operational parameters- enter service- real and reactive power control requirements	2
2.3	Response to area EPS abnormal conditions- voltage and frequency ride through requirements-	1
2.4	Flicker limit- Total Rated-Current Distortion (TRD)	1
2.5	Grounding considerations	1
3	Fault analysis- types of faults- symmetrical components- sequence representation of distribution networks- fault analysis- overcurrent protection- coordination of relays, reclosers, and sectionalizers and fuses-solid state circuit breaker- digital overcurrent detection (directional)- blinding of protection- sympathetic tripping- Islanding- intentional and unintentional-islanding detection and anti-islanding protection- passive, active and communication based techniques- Case studies	

3.1	Fault analysis- types of faults- Overview of symmetrical components	1
3.2	sequence representation of distribution networks- fault analysis	1
3.3	overcurrent protection- coordination of relays, reclosers, and sectionalizers and fuses-	2
3.4	solid state circuit breaker- digital overcurrent detection (directional)-blinding of protection- sympathetic tripping-	2
3.5	Islanding- intentional and unintentional- islanding detection and anti-islanding protection- passive, active and communication based techniques-	2
3.6	Case studies	1
4	Concept and definition of Microgrid- typical structure and configuration of ac microgrid- modes of operation and control- grid connected and islanded mode- Power converter topologies and control schemes for power sharing- droop control- communication based control- grid interactive power converters- features - current control- phase locked loops (PLL) and frequency locked loops (FLL)- Interconnection to grid- current control- Filter design- passive and active damping- active load management, DG active and reactive power dispatch, control of transformer taps- radial, loop and network distribution- voltage regulation and system reconfiguration	
4.1	Concept and definition of Microgrid- typical structure and configuration of ac microgrid	1
4.2	modes of operation and control- grid connected and islanded mode-	1

4.3	Power converter topologies and control schemes for power sharing- droop control- communication based control-	1
4.4	Grid interactive power converters- features - current control	1
4.5	Phase locked loops (PLL) and frequency locked loops (FLL)	1
4.6	Interconnection to grid- current control- Filter design- passive and active damping	2
4.7	Active load management, DG active and reactive power dispatch, control of transformer taps	1
4.8	radial, loop and network distribution- voltage regulation and system reconfiguration	1
5	DC microgrid- structure- grid connected and isolated modes of operation- overview of power electronic converters for DC microgrid - droop control- active load sharing- Hierarchical Control in DC microgrids Introduction to smart grids- smart metering- smart grid communication infrastructure, wide area monitoring systems (WAMS)- micro phasor measurement unit (PMU)- power quality issues in smart grids, regulatory standards- Impact of plug in EV- smart grid economics, demand side management and demand response analysis of smart grid- Case studies	
5.1	DC microgrid- structure- grid connected and isolated modes of operation- overview of power electronic converters for DC microgrid	2
5.2	Droop control- active load sharing- Hierarchical Control in DC microgrids	1
5.3	Introduction to smart grids- smart metering- smart grid communication infrastructure	1
5.4	Wide area monitoring systems (WAMS)- micro phasor measurement unit (PMU)	1

5.5	Power quality issues in smart grids, regulatory standards-Impact of plug in EV	1
5.6	smart grid economics, demand side management and demand response analysis of smart grid	1
5.7	Case studies	1

References:

1. IEEE Std 1547-2018 - IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces, DOI: 10.1109/IEEESTD.2015.7317469

2. Distributed Energy Resources: Connection Modeling and Reliability Considerations, Technical Report (NERC 2017)

3. Math H Bollen and Fainan Hassen, "Integration of distributed generation in the Power System", Wiley-IEEE, 2011

4. Qing-chang Zhong, "Power Electronics-enabled Autonomous Power Systems: Next Generation Smart Grids", Wiley-IEEE, 2020
5. H. Lee Willis, Walter G. Scott, "Distributed Power Generation – Planning and Evaluation", Marcel Decker Press, 2000
6. Naser Mahdavi Tabatabaei, Ersan Kabalci. Nicu Bizon, "Microgrid Architectures, Control and Protection Methods", Springer, 2020
7. W.J. Ruschel; A.W. Ashley, "Coordination of Relays, Reclosers, and Sectionalizing Fuses for Overhead Lines in the Oil Patch", IEEE Transactions on Industry Applications, 1989
8. "Evaluation of Anti-Islanding Schemes Based on Nondetection Zone Concept", Zhihong Ye, Amol Kolwalkar, Yu Zhang, Pengwei Du, and Reigh Walling, IEEE Transactions on Power Electronics, 2004
9. Manoj Lonkar, Srinivas Ponnaluri, "An Overview of DC Microgrid Operation and Control", 6th International Renewable Energy Congress (IREC), 2015
10. Nikos Hatziargyriou, "Microgrids: Architectures and Control", Wiley-IEEE Press, Year: 2013
11. Mohammad A. Abusara, Georgios I. Orfanoudakis, Babar Hussain, "Power Electronic Converters for Microgrids", John Wiley & Sons Singapore, 2014
12. A Keyhani, M Marwali, "Smart power grids", Springer, 2011
13. NPTEL Lecture series- Introduction to Smart Grid, Prof. N. P. Padhy and Prof. Premalata Jena
14. IEEE Std C37.112-2018 - IEEE Standard for Inverse-Time Characteristics Equations for Overcurrent Relays, DOI: 10.1109/IEEESTD.2019.8635630
15. IEEE Std 142-2007 - IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems, DOI: 10.1109/IEEESTD.2007.4396963

16. IEEE Std 929-2000 - IEEE Recommended Practice for Utility Interface of Photovoltaic (PV) Systems, DOI: 10.1109/IEEESTD.2000.91304
17. IEEE Std C57.12.44-2014, IEEE Standard Requirements for Secondary Network Protectors, DOI: 10.1109/IEEESTD.2014.6832425

CODE 222EEE003	MULTILEVEL INVERTERS AND MODULATION TECHNIQUES	CATEGORY	L	T	P	CREDIT
		Program Elective 3	3	0	0	3

Preamble:

This course aims to impart knowledge on the operation, control and operational issues and mitigation techniques of various multilevel inverters and modular multilevel inverters

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

CO 1	Identify suitable Multilevel Inverter topology
CO 2	Analyze the performance of the multilevel inverter topology
CO 3	Select a suitable PWM technique for ML inverter topology
CO 4	Analyze the operational issues and identify suitable mitigation methods
CO 5	Identify suitable Modular multilevel Inverter topology and control 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 1 (8 hrs)

Multilevel (ML) Inverters- Advantages- comparison with two-level inverters - Diode Clamped ML Inverter- Three level and Five level- Flying Capacitor multilevel inverter- Three level and Four levels- Cascaded multilevel inverters-Symmetrical and asymmetrical Topologies of CHB- Derived Multilevel Topologies- ANPC- T-type Multilevel Inverters- Packed U- cell topology- Hybrid Multilevel Topologies- open end winding scheme

Module 2 (7 hrs)

Modulation of Two level and Multilevel Inverters – Sinusoidal PWM- Third harmonic and Triple-n harmonic injection PWM- Concept of Space Vectors (SV) - Space Vector Modulation- Discontinuous PWM- basic schemes- advantages - SVM for ML inverters based on two level SVM algorithm

Module 3 (9 hrs)

Selection of voltage vectors for PWM- Identification of nearest vectors- duty cycle computation- vector selection and switching- classical approach- Hexagon decomposition method- Method based on hexagonal coordinate system- Identification of nearest vectors and dwell timings- Carrier based space vector modulation- Level shifted and phase shifted PWM-Fundamental frequency control schemes- Introduction to selective harmonic elimination for ML inverters

Module 4 (8 hrs)

Operational Issues- Neutral point voltage balancing in Diode Clamped Multilevel inverter- Losses-Capacitor voltage balancing in Flying capacitor Inverters - Charge Balance Using Phase shift PWM- Dynamic voltage balancing- Common mode voltage and reduction of bearing currents

Module 5 (8 hrs)

Modular multilevel Converters- Introduction- Advantages- principle of operation- submodule configurations, classical control methods- pulse width modulation schemes- Phase shifted carrier modulation scheme- voltage control- capacitor voltage balancing strategies, circulating current issues and control of circulating current- applications of Multilevel and modular multilevel inverters- applications in power systems- traction and automotive applications- case studies

Syllabus and Course Plan

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

No	Topic	No. of Lectures (40)
1	Multilevel (ML) Inverters- Advantages- Comparison with two-level inverters - Diode Clamped ML Inverter- Three level and Five level- Flying Capacitor multilevel inverter- Three level and Four levels- Cascaded multilevel inverters-Symmetrical and asymmetrical Topologies of CHB- Derived Multilevel Topologies- ANPC- T-type Multilevel Inverters-Packed U- cell topology- Hybrid Multilevel Topologies- open end winding scheme for ML inverter	
1.1	Multilevel (ML) Inverters- Advantages- Comparison with two-level inverters	1
1.2	Diode Clamped ML Inverter- Three level and Five level	1
1.3	Flying Capacitor multilevel inverter- Three level and Four levels	1
1.4	Cascaded multilevel inverters-Symmetrical and asymmetrical Topologies of CHB	1
1.5	Derived Multilevel Topologies- ANPC	1
1.6	T-type Multi-level Inverters- Packed U-cell topology	1
1.7	Hybrid Multilevel Topologies	1
1.8	Open end winding scheme for ML inverters	1
2	Modulation of Two level and Multilevel Inverters – Sinusoidal PWM- Third harmonic and Triple-n harmonic injection PWM- Concept of space Vectors (SV) - space vector Modulation (SVM)- discontinuous PWM - basic schemes- advantages- SVM for ML inverters based on two level SVM algorithm	
2.1	Modulation of Two level and Multilevel Inverters – Sinusoidal PWM	1
2.2	Third harmonic and Triple-n harmonic injection PWM	1
2.3	Concept of Space Vectors (SV) - Space Vector Modulation (SVM) for multilevel inverters	1
2.4	Discontinuous PWM- Basic schemes- Advantages	2
2.5	SVM for ML inverters based on two level SVM algorithm	2
3	Selection of voltage vectors for PWM- Identification of nearest vectors- duty cycle computation- vector selection and switching- classical approach- Hexagon decomposition method- Method based on hexagonal coordinate system- Identification of nearest vectors and dwell timings- Carrier based space vector	

	modulation- Level shifted and phase shifted PWM-Fundamental frequency control schemes- Introduction to selective harmonic elimination for ML inverters	
3.1	Selection of voltage vectors for PWM- Identification of nearest vectors- duty cycle computation- vector selection and switching- classical approach	2
3.2	Hexagon decomposition method- Identification of nearest vectors and dwell timings	2
3.3	Hexagonal Coordinate System- Identification of nearest vectors and dwell timings	1
3.4	Carrier based space vector modulation- Level shifted and phase shifted PWM	2
3.5	Fundamental frequency control schemes	1
3.6	Selective harmonic Elimination for ML inverters- Introduction	1
4	Operational Issues- Neutral point voltage balancing in Diode Clamped Multilevel inverter- Losses- Capacitor voltage balancing in Flying capacitor Inverters - Charge Balance Using Phase shift PWM- dynamic voltage balancing- Common mode voltage and reduction of bearing currents	
4.1	Operational Issues- Neutral point voltage balancing in Diode Clamped Multilevel inverter	2
4.2	Losses in ML inverters	2
4.3	Capacitor voltage balancing in Flying capacitor Inverters - Charge Balance Using Phase shift PWM- Dynamic voltage balancing	2
4.4	Common mode voltage and reduction of bearing currents	2
5	Modular multilevel Converters- Introduction- Advantages- principle of operation- submodule configurations, classical control methods- Pulse width modulation schemes- Phase shifted carrier modulation scheme- voltage control- capacitor voltage balancing strategies, circulating current issues and control of circulating current- applications of Multilevel and modular multilevel inverters- applications in power systems- traction and automotive applications- case studies	

5.1	Modular multilevel Converters- Introduction- Advantages- principle of operation-submodule configurations	2
5.2	Classical control methods- Pulse width modulation schemes- Phase shifted carrier modulation scheme- voltage control	2
5.3	Capacitor voltage balancing strategies	1
5.4	Circulating current issues and control of circulating current	1
5.5	Applications of Multilevel and modular multilevel inverters- applications in power systems- traction and automotive applications- case studies	2

References

1. D. Grahame Holmes, Thomas A Lipo, "Pulse Width Modulation for Power converters- Principles and Practice", John Wiley and sons, 2003

2. Ersan Kabalc, "Multilevel Inverters Introduction and emergent topologies" Academic Press, 2021

3. Daniel W. Hart, "Power Electronics", McGrawHill, 2011

4. Bin Wu, " High Power Converters and AC Drives". Wiley -IEEE 2006

5. S. Gonzales, S. Verne, M. Valla, "Multilevel Converters for Industrial Applications", CRC 2014

6. A.M. Trzynadlowski, "Introduction to Modern Power Electronics", Wiley, 2010

7. Nikola Celanovic, and Dushan Boroyevich, "A Fast Space-Vector Modulation Algorithm for Multilevel Three-Phase Converters", IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL. 37, NO. 2, MARCH/APRIL 2001

8. Jae Hyeong Seo, Chang Ho Choi and Dong Seok Hyun, "A New Simplified Space–Vector PWM Method for Three-Level Inverters", IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 16, NO. 4, JULY 2001

SLOT: C

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Branch: **Electrical and Electronics**

Stream(s): **Power Electronics/Electrical Machines**

Course Code: **CODE 222EEE003**

Name: **MULTILEVEL INVERTERS AND MODULATION TECHNIQUES**

Max. Marks: 60 Duration : 2.5 hours

Part A

(Answer all questions)

1. Compare and contrast three level NPC and T-type multilevel inverters (5)

2. Explain carrier based SPWM technique used in multi level inverter (5)

3. With the help of a neat figure, explain phase shifted carrier modulation scheme. Mention the advantages compared to level shifted PWM (5)

4. Discuss the effect of common mode currents on the bearings and the use of ML inverters to reduce the common mode currents (5)

5. With a neat figure, explain the space vector modulation of three level inverter based on two-level mapping of space vector diagram (5)

Part B

(Answer any five questions)

6. Illustrate the circulating current issues in Modular multilevel inverters and the control of circulating current (7)

7. Explain different types of voltage control techniques used in Modular Multilevel Converters (7)

8. Explain discontinuous PWM in two-level and Multi-level inverters (7)

9. Illustrate the operation of four-level flying capacitor inverter and any capacitor balancing scheme (7)

10. Explain hexagonal decomposition PWM for three level inverter (7)

11. Draw the circuit of a five-level cascaded multilevel inverter and explain its working. Also explain any fundamental frequency voltage control scheme (7)

12. Explain the neutral point voltage balancing issues in NPC inverters and discuss any one of the one possible remedies (7)

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE006	DIGITAL CONTROL SYSTEM DESIGN	PEC	3	0	0	3

Preamble: This course deals with Z-Plane Analysis of Discrete-Time Systems, design of digital controllers in time and frequency domains. Also it includes design using state space approach and study of multivariable systems

Course Outcomes:

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

CO 1	Analyse a discrete-time system and evaluate its performance
CO 2	Design suitable digital controller for the system to meet the performance specifications
CO 3	Design a digital controller and observer for the system and evaluate its performance
CO 4	Analyse a MIMO discrete-time 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			3	3	2		
CO 2			3	3	3		
CO 3			3	3	3		
CO 4			3	3	2		

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	
Analyse	
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

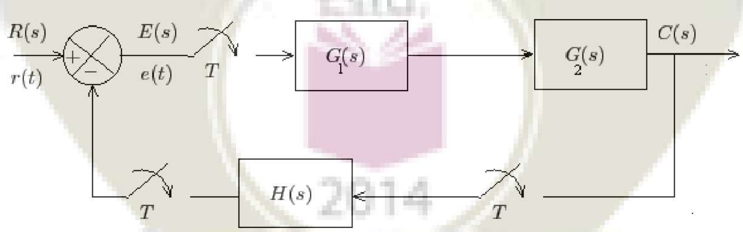
Continuous Internal Evaluation: 40 marks

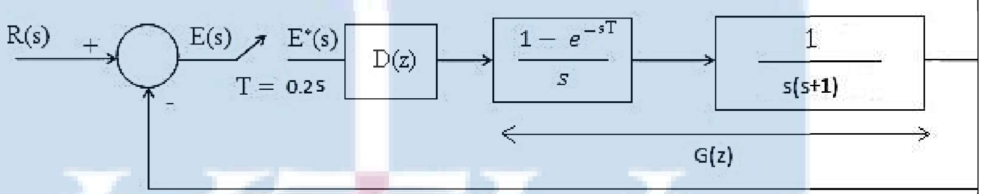
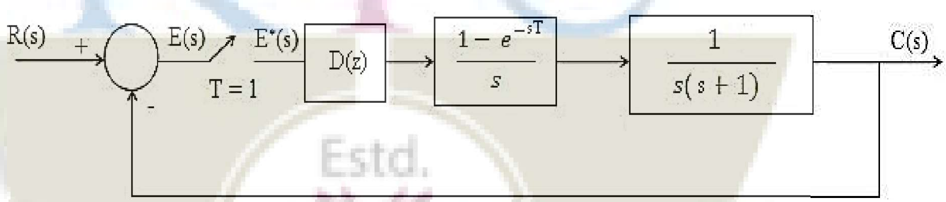
Preparing a review article based on peer reviewed
Original publications (minimum 10 publications shall be referred) : 15 marks
Course based task/Seminar/Data collection and interpretation : 15 marks

Test paper, 1 no. : 10 marks
Test paper shall include minimum 80% of the syllabus.
The project shall be done individually. Group projects not permitted. Test paper shall include minimum 80% of the syllabus.

End Semester Examination: 60 marks
The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving

Model Question paper

No. of Pages:3			**B**
		APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY FIRST SEMESTER M.TECH DEGREE EXAMINATION MONTH & YEAR	
		Branch: Electrical &Electronics Engineering	
		Course Code & Name: 2222EEE006 DIGITAL CONTROL SYSTEM DESIGN	
		Answer *all* questions from part A and any five questions from part B. Limit answers to the required points.	
Max. Marks: 60		Duration: 2.5 hours	
		PART A	
1.	a.	Explain the sampling process and loss of information and noise due to sampling	2
	b.	Obtain the z-transform of the function $f(k) = k^2 u(k)$, $where, u(k) = 1,\ k \geq 0,\ k < 0$	3
2.		Obtain the pulse transfer function of the system shown below:  	5
3.		For a unity feedback system, with sampling time T=1sec, open loop pulse transfer $G(z) = \frac{K(0.3679z + 0.2542)}{(z - 0.3679)(z - 1)}$. function is Determine the value of K for stability by use of Jury'sstability test. Also determine the frequency of oscillations at the output	5
4.		Explain controllability & observability of digital systems.	5
5.		Consider a multi output linear system described by the state model $x(k + 1) = Fx(k) + Gu(k)$ $y(k) = Cx(k) - Du(k)$	5

		where, $F = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -2 & 1 & -1 \end{bmatrix}, G = \begin{bmatrix} 0 & 1 \\ 1 & 0 \\ 1 & 1 \end{bmatrix}, C = \begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix}, D = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$ Check whether the system is observable	
		PART B	
6.		Consider the digital control system shown in figure. Design a digital controller D(z) such that the closed loop system has a damping ratio 0.5 and the number of samples per cycle of damped sinusoidal oscillation to be 0.8 	7
7.		For the system shown, find a. Phase margin of the system when D(z) =1 b. Design a unity dc gain phase lag compensator D (z) that yields a phase margin of approximately 45 degrees. 	7
8.		Explain the concept and procedure for designing a lag compensator using root locus method.	7
9.		For the system G(s)=1/(s (s+1)),design a lead compensator in z plane such that the compensated system will have a Phase margin of 45°.Assume the sampling period T to be 1 sec	7

	10		Consider the discrete time system defined by the equations $x(k+1) = Gx(k) + Hu(k)$, $y(k) = Cx(k)$ where $G = \begin{bmatrix} 0 & 0 & -0.25 \\ 1 & 0 & 0 \\ 0 & 1 & 0.5 \end{bmatrix}$, $H = \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix}$, $C = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix}$. Assuming that the output y(k) is measurable, design a minimum order observer, such that the error will exhibit deadbeat response	7
	11		Prove that if a discrete system is completely state controllable and observable, then there is no pole zero cancellation in the pulse transfer function.	7
	12		Explain the algorithm for placing poles in a multivariable system.	7

SYLLABUS

MODULE I (9 hours)

Z-Plane Analysis of Discrete-Time Systems: Review of Z Transforms-Sampling Theorem, Impulse Sampling and Data Hold, Sampling Rate Selection -Pulse Transfer Function, Mapping between the s-plane and the z-plane; Stability analysis of closed-loop system in the z-plane -Jury's test- Schur-Cohn test-Bilinear Transformation, Routh-Hurwitz method in w-plane

MODULE II (8 hours)

Digital Controller Design Based on Root locus Approach: Direct design based on root locus-
Design of Lag Compensator-Design of Lead Compensator-Design of Lead-Lag Compensator

MODULE III (8 hours)

Digital Controller Design in Frequency Domain: Direct design based on frequency response-
Design of Lag Compensator-Design of Lead Compensator-Design of Lag-Lead Compensator

MODULE IV (9 hours)

Design using State Space approach: Discretization of continuous time state-space equations-
Controllability-Observability; Design via Pole Placement-State Observer Design-Full order observers-Reduced order observers

MODULE IV (6 hours)

Multivariable Digital Systems: Solution of Linear Digital State Equations; Controllability/ Observability Indices; State feedback for MIMO systems

COURSE PLAN

No	Topic	No. of Lectures
1.1	z-Plane Analysis of Discrete-Time Systems	
1.1.1	Review of Z Transforms	2
1.1.2	Sampling Theorem, Impulse Sampling and Data Hold, Sampling Rate Selection	1
1.1.3	Pulse Transfer Function,	2
1.1.4	Mapping between the s-plane and the z-plane	1
1.2	Stability analysis of closed-loop system in the z-plane	
1.2.1	Jury's test, Schur-Cohn test,	2
1.2.2	Bilinear Transformation, Routh-Hurwitz method in w-plane	1

2	Digital Controller Design Based on Root locus Approach	
2.1	Direct design based on root locus	2
2.2	Design of Lag Compensator	2
2.3	Design of Lead Compensator	2
2.4	Design of Lead-Lag Compensator	2
3	Digital Controller Design in Frequency Domain	
3.1	Direct design based on frequency response	2
3.2	Design of Lag Compensator	2
3.3	Design of Lead Compensator	2
3.4	Design of Lag-Lead Compensator	2
4	Design using State Space approach	
4.1	Discretization of continuous time state-space equations	1
4.2	Controllability	1
4.3	Observability	1
4.4	Design via Pole Placement	2
4.5	State Observer Design,	
4.5.1	Full order observers	2
4.5.2	Reduced order observers	2
5	Multivariable Digital Systems	
5.1	Solution of Linear Digital State Equations	2
5.2	Controllability/ Observability Indices	1
5.3	State feedback for MIMO systems	3

Reference Books

1. C. L. Philips, H. T. Nagle, Digital Control Systems, Prentice-Hall, Englewood Cliffs, New Jersey, 1995.

2. M. Gopal, Digital Control and State Variable Methods, Tata McGraw-Hill, 1997.

3. K. Ogata, Discrete-Time Control Systems, Pearson Education, Asia.

4. R. G. Jacquot, Modern Digital Control Systems, Marcel Decker, New York, 1995.

5. Benjamin C. Kuo, Digital Control Systems, 2/e, Saunders College Publishing, Philadelphia, 1992.

6. Gene F. Franklin, J. David Powell, Michael Workman, Digital Control of Dynamic Systems, Pearson, Asia.

7. J. R. Liegh, Applied Digital Control, Rinchart& Winston Inc., New Delhi.

8. Frank L. Lewis, Applied Optimal Control & Estimation, Prentice-Hall, Englewood Cliffs NJ, 1992.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EE007	POWER SYSTEM DYNAMICS AND STABILITY	PEC	3	0	0	3

Preamble: This course deals with all the power system operational dynamics and stability aspects including case studies.

Course Outcomes:

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

CO 1	Model the essential elements of power system.
CO 2	Perform the small signal stability analysis of power system
CO 3	Perform transient stability analysis of power system
CO 4	Apply different voltage stability criteria in power system.
CO 5	Evaluate different power system stability enhancement methods

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	Continuous Assessment Tests	End Semester Examination
	1	
Remember		
Understand	20	20
Apply	30	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:

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,1no.: 10 marks (Test paper shall include minimum 80% of the syllabus.)

End Semester Examination Pattern:

There will be two parts; Part A and Part B.

Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (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.

Model Question paper

QP CODE: **PAGES: 1**

Reg No: _______________ **Name: __________________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 222EE007

Course name: POWER SYSTEM DYNAMICS AND STABILITY

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

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

1. Draw and explain power system control hierarchy?

2. Discuss the assumptions made in developing the equations of synchronous machines?

3. Explain rotor angle stability and how does the small disturbances effect on its stability?

4. Explain the Power-Angle relationship of synchronous machines in a power system.

5. Describe the principal factors contributing to voltage collapse

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

6. Explain the basic structure of power system with necessary diagram

7. Synchronous machine inductances are functions of rotor position. Justify.

8. Describe the state space representation and stability of a dynamic system?

9. Draw the small signal stability block diagram representation with constant field voltage and comment about its stability aspects

10. What is single pole switching and what are the problems that arise in application of this method?

11. Explain static analysis used for voltage stability

12. Conclude the significance inference from PV curve & QV curve and comment about the stable operating point & collapse region.

Syllabus

No	Power System Dynamics and Stability	Contact hours
1	Structure of power System and its controls. Concept of Power System Stability-Types of stability. **Modelling Power System Components:** Synchronous machine modelling: Mathematical Description of a Synchronous Machine - Basic equations of a synchronous machine. flux linkage equations, inductance matrix, Stator to stator self-inductance, mutual inductance, stator to rotor inductance, rotor to rotor inductance, Derivation of parks transformation matrix, physical concept, Inductance matrix in dqO frame.	9
2	Synchronous Machine Modelling (Continuation): voltage equations in stationary and dqO frame, Equivalent circuit for direct and quadrature axis, Per unit representation, Steady state equivalent circuit, Excitation system modelling, static excitation system only	8
3	**Small Signal Analysis** System state space representation, Eigen value and stability, Eigen vectors, state transition matrix, small signal stability of SMIB system, Effect of field flux variation on stability, Effect of exciter with AVR on stability, small signal stability enhancement by PSS	8
4	**Transient Stability** An Elementary View of Transient Stability. Response to a Step Change in Pm, Equal-Area Criterion, Response to a Short-Circuit Fault, Effect of short circuit at midpoint of one of the transmission lines of double circuit line, Effect of short circuit at sending end. Transient stability enhancement techniques	7
5	**Voltage stability** Concept of reactive power variation at sending end and receiving end of a simple system, Voltage stability analysis of PQ curve, QV curve and PV curve, generator steady state PQ capability curve, generator QV curves, Transmission characteristics on voltage stability, Static and dynamic characteristics of load components, Sensitivity analysis, voltage collapse and its prevention	8

Course Plan

No	Topic	No. of Lectures
1	**Power System structure, control and Components Modelling**	
1.1	Structure of power System and its controls	1
1.2	Concept of Power system stability-Types of stability	1
1.3	Synchronous Machine Mathematical Description of a Synchronous Machine. Basic equations of a synchronous machine	2
1.4	Flux linkage equations, inductance matrix, Stator to stator self-inductance, mutual inductance, stator to rotor inductance, rotor to rotor inductance,	2
1.5	Derivation of parks transformation matrix, physical concept	1
1.6	Inductance matrix in dqO frame	2
2	**Synchronous Machine Modelling (Continuation):**	
2.1	voltage equations in stationary and dqO frame,	2
2.2	Equivalent circuit for direct and quadrature axis,	2
2.3	Per unit representation,	1
2.4	Steady state equivalent circuit	2
2.5	Excitation system modelling, static excitation system only	1
3	**Small Signal Analysis**	
3.1	System state space representation, Eigen value and stability, Eigen vectors, state transition matrix,	2
3.2	Small signal stability of SMIB system,	2
3.3	Effect of field flux variation on stability, Effect of exciter with AVR on stability,	2
3.4	Small signal stability enhancement by PSS	2
4	**Transient Stability**	
4.1	An Elementary View of Transient Stability.	1
4.2	Response to a Step Change in Pm, Equal-Area Criterion,	2
4.3	Response to a Short-Circuit Fault,	1
4.4	Effect of short circuit at midpoint of one of the transmission lines of double circuit line, Effect of short circuit at sending end.	2
4.5	Transient stability enhancement techniques	1
5	**Voltage stability**	
5.1	Concept of reactive power variation at sending end and receiving end of a simple system,	2
5.2	Voltage stability analysis of PQ curve, QV curve and PV curve,	2
5.4	generator steady state PQ capability curve, generator QV curves,	1
5.5	Transmission characteristics on voltage stability, Static and dynamic characteristics of load components,	1

5.6	Sensitivity analysis, voltage collapse and its prevention	2

References

1. Kundur P, “Power System Stability and Control”, TMH

2. Anderson and Fouad, “Power System Control and Stability”, Galgotia Publications, Compensation 1981

3. Ramanujam R, “Power System Dynamics- Analysis & Simulation”, PHI learning Private Limited.

4. Padiyar K R, “Power System Dynamics”, 2nd Edition, B.S. Publishers, 2003.

5. Sauer P W & Pai M A,” Power System Dynamics and Stability”, Pearson, 2003.

6. Olle I Elgerd, “Electric Energy Systems Theory an Introduction”, 2nd Edition, McGraw-Hill, 1983.

7. Kimbark E W, “Power System Stability”, McGraw-Hill Inc., 1994, Wiley & IEEE Press, 1995.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE008	DESIGN OF POWER ELECTRONIC SYSTEMS	PEC	3	0	0	3

Preamble: Proper design and selection of power electronic components is crucial for the successful and reliable operation of power electronic products. This course enables the students to design suitable gate drives, power stage and cooling systems for power electronic converters meeting EMC standards. A basic course on Power Electronics is desirable as prerequisites for the course.

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

CO 1	Develop gate drive schemes for different types of switching devices after understanding pertinent limitations of simple drive schemes
CO 2	Analyse different gate drive schemes and design protection circuits and snubbers
CO 3	Do loss calculation and design cooling systems
CO 4	Design of magnetics, filter capacitors and bus bars
CO 5	Design of power converters for Electromagnetic Compatibility

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	25 %
Analyse	25 %

Evaluate	25 %
Create	25%

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

Mod.I (9 hrs) High frequency diodes- reverse recovery issues- fast and soft recovery- schottky diodes- loss computation in diodes- base/gate drive requirements - design of base/gate drive for Power transistors, MOSFET and IGBTs- dc coupled drive circuits- isolated drive circuits, bootstrapping - cascode transistor driver- gate drive considerations for SiC MOSFET- Gate drive power requirements- Protection in drive circuits- dead time requirements- overcurrent and desaturation protection- Noise suppression- ferrite beads- pcb layout considerations for gate drives

Mod.II (7 hrs) Snubber circuits- Need for snubber- diode snubbers - Safe Operating Area (SOA) of switching devices- Device loss computation with and without snubber- design of turn-off and turn-on snubbers- energy recovery snubbers- snubber for bridge circuit configurations

Mod.III (7 hrs) Cooling and design of heat sinks- heat transfer by conduction, radiation and convection- thermal analogy- control of device temperature- selection of heat sink- thermal resistance due to radiation and convection-natural cooling- Forced air cooling- pulsed power and transient thermal impedance

Mod. IV (9 hrs) Design of inductors -selection of core material and size- core loss and winding losses- reduction of skin effect- leakage inductance- design of high frequency transformers for sine wave and square wave inverters, push-pull, half bridge, full bridge, fly back and forward converters- selection of filter capacitors- bus bars- Case study: design of buck converter, quadratic buck, fly black and single phase PWM rectifier

Mod. V (8 hrs) EMI and EMC- Introduction- characteristics of switching processes of power devices- Electromagnetic compatibility (EMC)- conductive and radiative EMI- standards- reduction of EMI- common mode filter-LISN- Shielding of cables and transformers- PCB layout considerations - Case study: buck converter, forward and fly black converters

Course Plan

No	Topic	No. of Lectures
1	**Module 1 (9 hrs)** High frequency diodes- reverse recovery issues- fast and soft recovery- schottky diodes- loss computation in diodes- base/gate drive requirements - design of base/gate drive for Power transistors, MOSFET and IGBTs- dc coupled drive circuits- isolated drive circuits, bootstrapping - cascode transistor driver- gate drive considerations for SiC MOSFET- Gate drive power requirements- Protection in drive circuits- dead time requirements- overcurrent and desaturation protection- Noise suppression- ferrite beads- pcb layout considerations for gate drives	
1.1	High frequency diodes- reverse recovery issues- fast and soft recovery- schottky diodes- loss computation in diodes	1
1.2	Base drive requirements - design of base drive for Power transistors- dc coupled drive circuits- isolated drive circuits,cascode driver	2
1.3	Gate drive requirements- Design of base gate drive for MOSFETs and IGBTs- dc coupled drive circuits- isolated drive circuits, bootstrapping	2
1.4	Gate drive considerations for SiC MOSFET	1
1.5	Gate drive power requirements	1
1.6	Protection in drive circuits- dead time requirements- overcurrent and desaturation protection	1
1.7	Noise suppression- ferrite beads- pcb layout considerations for gate drives	1
2	**Mod.II (7 hrs)** Snubber circuits- Need for snubber- diode snubbers - Safe Operating Area (SOA) of switching devices- Device loss computation with and without snubber- design of turn-off and turn-on snubbers- energy recovery snubbers- snubber for bridge circuit configurations	
2.1	Snubber circuits- Need for snubber- diode snubbers	2
2.2	Safe Operating Area (SOA) of switching devices- device loss computation with and without snubbers	1
2.3	Design of turn-off and turn-on snubbers	2

2.4	Energy recovery snubbers	1
2.5	snubber for bridge circuit configurations	1
3	**Mod.III (7 hrs)** Cooling and design of heat sinks- heat transfer by conduction, radiation and convection- thermal analogy- control of device temperature- selection of heat sink- thermal resistance due to radiation and convection-natural cooling- Forced air cooling- pulsed power and transient thermal impedance	
3.1	Cooling and design of heat sinks- heat transfer by conduction, radiation and convection	1
3.2	Thermal analogy- control of device temperature	1
3.3	Selection of heat sink	1
3.4	Thermal resistance due to radiation and convection- Natural cooling	2
3.5	Forced air cooling of heat sinks	1
3.6	Pulsed power and transient thermal impedance	1
4	**Mod. IV (9 hrs)** Design of inductors -selection of core material and size- core loss and winding losses- reduction of skin effect- leakage inductance- design of high frequency transformers for sine wave and square wave inverters, push-pull, half bridge, full bridge, fly back and forward converters- selection of filter capacitors- bus bars- Case study: design of buck converter, quadratic buck, fly black and single phase PWM rectifier	
4.1	Design of inductors -selection of core material and core size	1
4.2	Core loss and winding losses	1
4.3	Reduction of skin effect and leakage inductance	1
4.4	Design of high frequency transformers for sine wave and square wave inverters	1
4.5	Design of high frequency transformer for push-pull, half bridge, full bridge	1
4.6	Design of high frequency transformers for Fly back and forward converters	1
4.7	Selection of filter capacitors	1

4.8	Design of bus bars	1
4.9	Case study: design of buck converter, quadratic buck, fly black converter and single phase PWM rectifier	1
5	EMI and EMC- Introduction- characteristics of switching processes of power devices- Electromagnetic compatibility (EMC)- conductive and radiative EMI-standards- reduction of EMI- common mode filter-LISN- Shielding of cables and transformers- PCB layout considerations - Case study: buck converter, forward and fly black converter	
5.1	**Mod. V (8 hrs)** EMI and EMC- Introduction- characteristics of switching processes of power devices- Electromagnetic compatibility (EMC)- conductive and radiative EMI- standards- reduction of EMI- common mode filter-LISN- Shielding of cables and transformers- PCB layout considerations - Case study: buck converter and fly black converter	1
5.2	Characteristics of switching processes of power devices	1
5.3	Electromagnetic compatibility (EMC)- conductive and radiative EMI- standards	2
5.4	Reduction of EMI- common mode filter- LISN	2
5.5	Shielding of cables and transformers	
5.5	PCB layout considerations	1
5.6	Case study: buck converter, forward and fly black converters	1

Reference Books

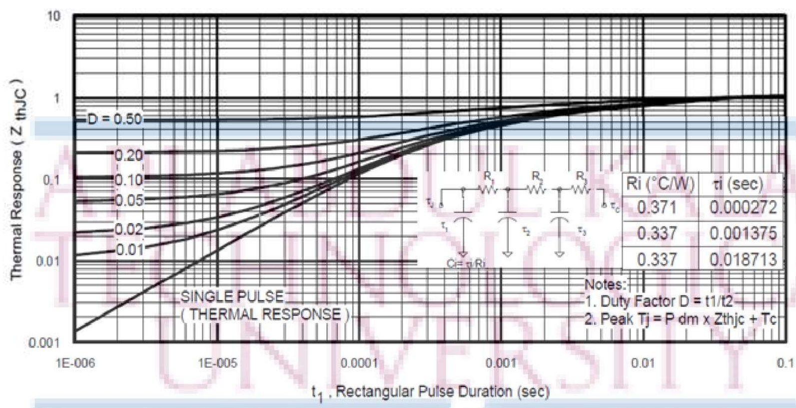
1. Ned Mohan, Tore M. Undeland and William P.Riobbins, “ Power Electronics—Converters, Applications and Design” Third Edition, John Wiley and Sons. Inc2014
2. L. Umanand, “Power Electronics-Essentials and Applications”, Wiley, 2014
3. Daniel W. Hart, “Power Electronics”, Tata McGraw Hill, 2011
4. H.W. Whittington et al., “Switched Mode Power Supplies- Design and Construction”, University Press, 1997
5. Francois Costa et al., “Electromagnetic compatibility in Power Electronics”, Wiley Iste, 2014
5. Joseph Vithayathil, “ Power Electronics-Principle and Applications” , Tata McGraw Hill Education Pvt Ltd, 2010.

Model Question paper

	Model Question paper	**Slot D**
APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY		
FIRST SEMESTER M.TECH DEGREE EXAMINATION MONTH & YEAR		
Course code: 222EEE008	**Course Name: DESIGN OF POWER ELECTRONIC SYSTEMS**	
Max. Marks: 60		Duration: 2.5 Hours

PART A				
Answer all Questions. Each question carries 5 Marks				
Sl. No	Question	Marks	CO	BL
1	List the important drive requirements of a good BJT drive	5	1	1
2	An RCD snubber is used in a MOSFET based laptop car battery adapter (12 V to 19 V, 2.5 A current output). Calculate the turn-off loss with and without the snubber. The MOSFET is switched at 100kHz and the MOSFET has a turn-off delay time of 90ns and current fall time of 80ns.	5	2	2
3	What do you mean by thermal resistance? Explain how its value can be reduced in a heat sink? Also explain the electrical equivalent model of a typical heat sink arrangement	5	3	1
4	Calculate the skin depth at 2kHz, and at 200kHz for enamelled copper conductors and hence suggest the conductor(s) size to carry a current of 5A RMS at these frequencies. Justify the selection	5	4	3

5	Explain the PCB layout considerations in a flyback converter for EMI reduction	5	5	1
	PART –B			
	(Answer any five questions, each question carries 7 marks)			
6	(a) A MOSFET needs 250nC of total gate charge to turn ON. Determine the gate current needed if the MOSFET needs to be turned ON in about 350ns. Draw a suitable gate drive scheme. If the MOSFET is used in an application where the switching frequency is 25kHz, what is the minimum duty cycle percentage possible if the device turn-OFF time is 250ns.	3	1	2
	(b) What do you mean by cascode-connected drive circuits? Explain	4	1	1
7	(a) Explain the need for snubber network for fast recovery diodes and obtain design equations for the snubbers	3	2	1
	(b) Draw the instantaneous voltage, current and power waveforms across a typical IGBT during turn-off, without and with an RCD snubber. Determine the value of turn-off snubber capacitor for which total loss at turn-off is minimum	4	2	2
8	(a) A power pulse of 500W with a 10µs duration and a duty cycle of 0.2 occurs in a MOSFET that has transient thermal resistance characteristics as shown in figure below. Determine the maximum junction temperature, if the case temperature is 80 C.	3	3	3



	(b) A student used IRFZ44 MOSFET without any heatsink in a switching regulator application where the switching loss is 1.5W and conduction loss is 0.85W. The thermal resistance RΘj-a of the MOSFET is 62 □C/W. What is the typical temperature at the junction at this operating condition? Is the design acceptable? Give your comments.	4	3	3
9	(a) Select suitable airgap length and number of turns for the transformer in a forward converter. Use EE42/21/20 ferrite core. It is given that battery Voltage=12V, Output voltage=200V, Output power=20W, Switching frequency=25kHz. Make suitable assumptions	3	4	4
	(b) An inductor is constructed with a U-shaped ferrite core. The core has an area of cross section 200mm2 and mean magnetic path length of 12 cm. The relative permeability of the core is 3000. Calculate the inductance when 55 turns are used for the coil. What is the value of inductance when an air-gap of 4mm is introduced in the flux path?	4	4	2
10	(a) Design and select each component of a suitable dc-dc converter with input voltage 100V and output voltage of 10V. Output power = 2000W. Switching frequency 10 kHz, Assume all other required data. Justify your selection of components.	3	5	4
	(b) 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	4	5	1

11	(a) Illustrate the design of the gate drive circuit for For Si MOSFET	3	4	1
	(b) In a flyback converter, the dc input voltage is 320V and output voltage is 20V. The transformer has a turns ratio of 10:1 and a leakage inductance of 400μH as measured on the high voltage side. The transistor which can be considered as an ideal switch, is driven by a 50KHz square wave. The fast recovery diode of the converter has a reverse recovery time of 100ns (i) Draw the circuit diagram and an equivalent circuit suitable for diode snubber design calculations (ii) Determine suitable snubber capacitor and resistance for the diode	4	4	3
12	(a) Illustrate the design of the gate drive circuit for For SiC MOSFET	3	1	1
	(b) A 5V microcontroller PWM port has current sourcing/sinking capability of 10mA only.Hence, a transistor-based gate drive circuit is needed as the gate driver to drive a power MOSFET in a 5V to 19V boost converter application (i) Draw the circuit diagram of the microcontroller interface and the driver (ii) Design a gate driver circuit so that the MOSFET can operate properly at a switching frequency of 100kHz. Make suitable assumptions	4	2	4

CODE	COURSE NAME	CATEGORY	L	T	P	CREDITS
222EEE009	**ELECTRIC VEHICLE SYSTEM DESIGN**	Program Elective - 4	3	0	0	3

Preamble:

Electric vehicles are currently the dominant technologies in the new generation of automobiles. Electrical vehicles intergrate many subsystems and reliable operation of all subsystems is essential for the smooth working of EVs. This course covers the design aspects of EVs including vehicle dynamics, battery pack, battery management system and control of motor drives.

Course Outcomes:

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

CO 1	Analyse vehicle dynamics with various traction forces in an electric vehicle
CO 2	Apply the concepts of battery management systems and design battery pack for EVs
CO 3	Model and design EV motor drive and control based on PMSM
CO 4	Model conductive and inductive charging circuits used in EVs

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10 Publications shall be referred)	**15 marks**
Course based task/Seminar/Data Collection and interpretation	**15 marks**
Internal exam 1 no	**10 marks**

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 carries 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 PAGES: 2 QP CODE:XXXXX	
Reg.No:______________	Name:__________________

SLOT: D

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SECOND SEMESTER MTECH DEGREE EXAMINATION
MONTH & YEAR

Course Code: **222EEE009**

Course Name: **ELECTRIC VEHICLE SYSTEM DESIGN**

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

PART A
Answer all questions
Each question carries 5 marks - 25 marks

1		Estimate the range of an electric vehicle at 120 km/h with battery energy of 90 kWh, efficiency of the powertrain from the battery to the transmission is 85%. Take road-load force constants as A= 177.2, B= 1.445 and C=0.354.	5
2		Calculate the number of cells required in series and parallel modules of a battery pack used in an EV bike with a motor of rating 480W 48V with a back-up of 10hours. Also, find the weight of the battery pack if a Li-ion battery of 3.6V, 2000mAh cells having weight of 65grams are used.	5
3		A two pole IPMSM is running at 3600 rpm in the steady state. The stator coil resistance is rs = 0.01 Ω. The operating conditions are: phase voltage $\mathbf{v}^s_{abc} = -100\left[\sin(377t+\frac{\pi}{3}), \sin(377t-\frac{\pi}{3}), \sin(377t-\pi)\right]^T,$ back EMF $\mathbf{e}^s_{abc} = -125\left[\sin(377t), \sin(377t-\frac{2\pi}{3}), \sin(377t-\frac{4\pi}{3})\right]^T,$ current $\mathbf{i}^s_{abc} = -50\left[\sin(377t+\frac{\pi}{4}), \sin(377t-\frac{5\pi}{12}), \sin(377t-\frac{13\pi}{12})\right]^T$ Determine L_d and L_q	5
4		Derive the expression for i_{de} for a PMSM to achieve the maximum torque per ampere (MTPA).	5
5		Differentiate between conductive dc charging and inductive ac charging related to battery charging.	5
		PART B **Answer any five full questions** **7 marks each - 35 marks**	
6		Derive expressions for calculating acceleration time and acceleration energy.	7
7		Estimate the 0 to 60 mph acceleration time and energy for the 2015 Nissan Leaf as per the parameters given in the table below . Ignore all road loads and the internal moment	

of inertia assuming a gear efficiency of 97%.

	Unit	Rated speed	Maximum speed
Vehicle speed, v	km/h	43.61	144
	m/s	12.11	40
Rotor angular speed, ω_r	rad/s	314.96	1040
Rotor frequency, f_r	Hz	50.13	165.52
Rotor rpm, N_r	rpm	3008	9931

8 Determine the beginning-of-life kilowatt-hour storage required in an EV battery pack based on the following requirements: eight years of operation, an average of 48 km of driving per day s_{day} over the 365 days of the year, daily charging, and an average battery output energy per kilometre, E_{km} = 180 Wh/km. Assume L = 1 and $N_{100\%}$ =1000. Assume two parallel battery strings with 96 Li-ion cells per string, with a total number of cells N_{cell} = 192, and a nominal voltage of 3.75 V per cell. Determine the ampere-hours per cell. What are the vehicle ranges at BOL and EOL? 7

9 Derive the battery voltage, V_b, as a function of I_b and DOD from the static battery equivalent circuit model of battery. Calculate the voltage range for a cell used in a HEV application with a DOD of 25% to 75% and a load ranging from no-load to a full load of 6C. Also, find the battery pack voltage if there are 192 cells arranged with 96 cells in series and two strings in parallel. 7

10 A PM dc machine is used as the traction motor for an electric vehicle. The basic specifications for the machine are Pr(rated) = 80 kW and Tr(rated) = 280 Nm output at rated speed, a gear ratio n_g = 8.19, and a wheel radius r = 0.315 m. Given: back emf Ea is 220 V at rated speed, armature resistance Ra = 50 mΩ, and no-load torque T_{nl} = 2 Nm. Determine the armature voltage and current output by the dc-dc converter and the machine efficiency when the vehicle is operating under the following conditions: 7

a) Motoring up a hill and developing full torque at rated speed
b) Cruising and developing 70 Nm at the rated speed
c) Cruising and developing 70 Nm at half the rated speed.

11 An IPMSM has its parameters as shown in the following table. 7

No. of poles	6	Power (peak)	15 kW
DC link voltage (V_m)	300 V	Base speed	4550 rpm
Inductance (L_d)	3.05 mH	Rated current (I_m)	40 A
Inductance (L_q)	6.2 mH	Flux (ψ_m)	0.0948 Wb

a) Determine the d and q axis current yielding the maximum torque under the voltage constraint at 20000 rpm. b) Determine torque, power, and power factor at that point. In calculating the power factor, assume that the motor is lossless.

12 Sketch the circuit diagram of a low power charger and determine the expression for the dc charging current. 7

Syllabus:

Module 1 (9 hours):

Vehicle Dynamics & Load Forces : Power - Energy and Speed Relationship; Calculation of range; Vehicle Load Forces: Aerodynamic Drag – Calculation of aerodynamic drag force and power with no wind and windy conditions; Rolling Resistance - Calculation of rolling resistance force and power - Grading Resistance; Vehicle Acceleration - motive force (road load force) and motive torque - axle torque - traction torque; Calculation of motor power from traction torque - Vehicle acceleration by neglecting the load forces – calculation of acceleration time and acceleration energy.

Module 2 (8 hours):

Batteries and Battery Packs: Battery Pack– calculation of cells in pack (series and parallel)- calculation of battery pack weight from single cell weight - units of battery energy storage - capacity Rate; Battery Parameters- cell voltage - specific energy - cycle life - self-discharge; Lifetime and Sizing Considerations -Time and charge/discharge cycles - Lifetime - Beginning of life (BOL) - End of life (EOL) - DOD - Examples of Battery Sizing; BMS - Battery Charging - Protection and Management Systems; Static battery equivalent circuit model - Series-parallel battery pack equivalent circuits - Efficiency of Battery Pack - Determination of pack Voltage Range for EV - Determination of Cell/Pack Voltage for a Given Output\Input Power.

Module 3 (9 hours):

EV Machine Control: Motoring using a PM DC Machine - DC motor electric drive using dc-dc converter - Generating/Braking using a PM DC Machine - Motoring in Reverse; Review of PMSM dynamic equations - Equivalent circuit of PMSM in dq axis- Torque Equation; PMSM control - Control architecture of PMSM using the coordinate transformation map.

Module 4 (9 hours):

Design of EV controller using PMSM: Machine sizes under same power rating - Current Voltage and Speed Limits; Torque versus Current Angle - constant power speed range (CPSR) - Torque Speed Profile - constant power speed range; MTPA, MTPV.

EV motor requirements - Method of drawing torque-speed curve - (torque, power, current angle) using any computing tool - PMSM control in practice: Coil resistance measurement-back emf measurement - inductance measurement; Experiment for determining reference current Table - EV control block diagram with current look up table (LUT) and voltage anti-windup.

Module 5 (7 hours):

Battery Charging: Basic requirements for charging system - Charger architectures for onboard and offboard chargers, Constant Current and Constant Voltage (CC-CV) charging-V2G operation -input power factor correction, IEEE519, Wireless charging schemes; Charging standards-Automotive standard charger, SAE J1772 - Voltage and current levels, VDE-AR-E

2623-2-2, IEC 62196, DC charging technology - CHAdeMo, Combined Charging System (CCS) charger.

Course Plan

No	Topic	No. of Lectures
1	**Vehicle Dynamics & Load Forces :**	
1.1	Power, Energy, and Speed Relationship and calculation of range.	1
1.2	Vehicle Load Forces: Aerodynamic Drag – Calculation of aerodynamic drag force and power with no wind and windy conditions, Rolling Resistance - Calculation of rolling resistance force and power, Grading Resistance	3
1.3	Vehicle Acceleration: motive force (road load force) and motive torque - axle torque - traction torque	2
1.4	Calculation of motor power from traction torque - Vehicle acceleration by neglecting the load forces – calculation of acceleration time and acceleration energy.	2
2	**Batteries and Battery Packs:**	
2.1	Battery Pack– calculation of cells in pack (series and parallel), Calculation of Battery pack weight from single cell weight, Units of Battery Energy Storage, Capacity Rate, Battery Parameters-cell voltage, specific energy, cycle life, self-discharge	3
2.2	Lifetime and Sizing Considerations -Time and charge/discharge cycles, Lifetime, Beginning of life (BOL), End of life (EOL), DOD - Examples of Battery Sizing	2
2.3	BMS - Battery Charging, Protection, and Management Systems- Static battery equivalent circuit model. Series-parallel battery pack equivalent circuits - Efficiency of Battery Pack - Determination of pack Voltage Range for EV - Determination of Cell/Pack Voltage for a Given Output\Input Power	3
3	**EV Machine Control:**	
3.1	Motoring using a PM DC Machine - DC motor electric drive using dc-dc converter - Generating/Braking using a PM DC Machine - Motoring in Reverse	2
3.2	Review of PMSM dynamic equations - Equivalent circuit of PMSM in dq axis- Torque Equation	3
3.3	PMSM control - Control architecture of PMSM using the coordinate transformation map	3
4	**Design of EV controller using PMSM**	
4.1	Machine sizes under same power rating- Current Voltage and Speed Limits	2
4.2	Torque versus Current Angle- constant power speed range (CPSR)- Torque Speed Profile- constant power speed range, MTPA- MTPV	3
4.3	EV motor requirements- Method of Drawing Torque-Speed Curve -(torque, power, current angle) using any computing tool- PMSM control in practice: Coil resistance measurement, back emf measurement, inductance measurement, Experiment for determining reference current Table - EV control block diagram with current LUT and voltage anti-windup.	3

5	**Battery Charging:**	
5.1	Basic Requirements for Charging System- Architectures for onboard charging	2
5.2	Offboard chargers architecture	1
5.3	Constant Current and Constant Voltage (CC-CV) charging-V2G operation	2
5.4	input power factor correction, IEEE519, Wireless charging schemes	1
5.5	Automotive standard charger SAE J1772 levels- Voltage and current, VDE-AR-E 2623-2-2-IEC 62196, DC charging technology - CHAdeMo.-Combined Charging System (CCS) charger.	2

References

1. John G. Hayes ,G. Abas Goodarzi, "Electric Powertrain : Energy Systems, Power Electronics and Drives for Hybrid, Electric and Fuel Cell Vehicles", John Wiley & Sons Ltd, 2018

2. Kwang Hee Nam, "AC Motor Control and Electrical Vehicle Applications", Second Edition, CRC Press Taylor & Francis Group 6000 Broken Sound Parkway NW, Suite 300, 2019

3. John M. Miller, "Propulsion Systems for Hybrid Vehicles", Published by The Institution of Engineering and Technology, London, United Kingdom, Second Edition, 2010.

4. K. T. Chau, "Electric Vehicle Machines And Drives Design, Analysis And Application", 5 John Wiley & Sons Singapore Pte. Ltd, 2015.

222EEE070	Energy Efficiency in Electrical Engineering	CATEGORY	L	T	P	CREDIT
		PEC	3	0	0	3

Preamble: The course aims to understand various forms & elements of energy and evaluate the techno economic feasibility of the energy conservation technique adopted.

Course Outcomes:

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

CO 1	Understand the various forms & elements of energy.
CO 2	Assess energy efficiency in Electrical Supply System and Motors
CO 3	Analyse energy Efficiency in Electrical Utilities .
CO 4	Identify methods of energy conservation in Lighting , DG systems and transformers
CO 5	Evaluate energy efficient technologies in Electrical Systems

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	**End Semester Examination (marks in percentage)**
Apply	30
Analyse	40
Evaluate	30
Create	

Mark distribution

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

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed Original publications (minimum 10 publications shall be referred) : 15 marks

Course based task/Seminar/Data collection and interpretation: 15 marks

Test paper, 1 no. : 10 marks (Test paper shall include minimum 80% of the syllabus.)

End Semester Examination Pattern:

The end semester exam 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.

Model Question paper

QP CODE: **PAGES: 2**

Reg No:____________ **Name:________________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, MONTH & YEAR

Course name: Energy Efficiency in Electrical Systems

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

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

1) State the meaning and need of Energy Conservation.

2) List any four factors to be considered while selecting motor for any particular application.

3) Explain the concept of Energy Efficiency Ratio (EER)

4) Compare conventional core transformer with amorphous core transformer on the basis of i) Construction ii) Material used iii) Losses and iv) Cost

5) State any four benefits of Variable Frequency Drives (VFDs).

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

6) Explain the impact of energy usage on climate.

7) State three advantages of improvement of Power Factor at Load side.

Power Factor at the load side is 0.75 and average minimum load is 100 kW. What is the kVAr rating of capacitor to improve the Power Factor at the load side to 0.95 ?

8) A 50 kw induction motor with 86% full load efficiency is being considered for replacement by a 89% efficiency motor. What will be the saving in energy if motor works for 6000 hrs. per year and cost of energy is Rs. 4.50 per kwh?

9) What are the factors affecting the performance and savings opportunities in HVAC

10) What are the energy efficiency opportunities in DG systems?

11) What is energy efficient motors? Explain with technical aspects.

12) Explain different energy efficient lighting control with features.

Syllabus

Module 1: Energy Scenario:

Classification of energy, Capacity factor of solar and wind power generators, Global fuel reserve, Energy scenario in India, Impact of energy usage on climate, Salient features of Energy Conservation Act 2001 & The Energy Conservation (Amendment) Act, 2010 and its importance. Prominent organizations at centre and state level responsible for its implementation, Standards and Labelling.

Module 2: Energy Efficiency in Electrical Supply System and Motors

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

Module 3: Energy Efficiency in Electrical Utilities

Pumps: Introduction to pump and its applications, Efficient pumping system operation, Energy efficiency in agriculture pumps, Tips for energy saving in pumps
Compressed Air System: Types of air compressor and its applications, Leakage test, Energy saving opportunities in compressors.
HVAC and Refrigeration System: Introduction, Concept of Energy Efficiency Ratio (EER), Energy saving opportunities in Heating, Ventilation and Air Conditioning (HVAC) and Refrigeration Systems
Fans and blowers: Types, performance evaluation, efficient system operation, flow control strategies and energy conservation opportunities.

Module 4 : Energy Efficiency in Lighting , DG systems and transformers

Lighting Systems: Basic definitions- Lux, lumen and efficacy, Types of different lamps and their features, Energy efficient practices in lighting
DG Systems: Introduction, Energy efficiency opportunities in DG systems, Loading estimation
Transformers: Introduction, Losses in transformer, transformer Loading, Tips for energy savings in transformers

Module 5 :Energy Efficient Technologies in Electrical Systems

Maximum demand controllers, automatic power factor controllers, energy efficient motors, soft starters with energy saver, variable speed drives, energy efficient transformers, electronic ballast, occupancy sensors, energy efficient lighting controls, energy saving potential of each technology.
Course Plan

No	Topic	No. of Lectures
1	**Energy Scenario (6hours)**	
1.1	Classification of energy- primary and secondary energy, commercial and non-commercial energy, non-renewable and renewable energy with special reference to solar energy, Capacity factor of solar and wind power generators.	2
1.2	Global fuel reserve, Energy scenario in India, Impact of energy usage on climate	1
1.3	Salient features of Energy Conservation Act 2001 & The Energy Conservation (Amendment) Act, 2010 and its importance. Prominent organizations at centre and state level responsible for its implementation.	2
1.4	Standards and Labelling: Concept of star rating and its importance, Types of product available for star rating	1
2	**Energy Efficiency in Electrical Supply System and Motors (7hours)**	
2.1	Electrical system: Electricity billing, electrical load management and maximum demand control, power factor improvement and its benefit.	2
2.2	Selection and location of capacitors, performance assessment of PF capacitors, distribution and transformer losses	2
2.2	Electric motors: Types, losses in induction motors, motor efficiency, factors affecting motor performance, rewinding and motor replacement issues, energy saving opportunities with energy efficient motors.	3
3	**Energy Efficiency in Electrical Utilities (8hours)**	
3.1	Pumps: Introduction to pump and its applications, Efficient pumping system operation, Energy efficiency in agriculture pumps, Tips for energy saving in pumps	2
3.2	Compressed Air System: Types of air compressor and its applications, Leakage test, Energy saving opportunities in compressors.	2
3.3	Energy Conservation in HVAC and Refrigeration System: Introduction, Concept of Energy Efficiency Ratio (EER), Energy saving opportunities in Heating, Ventilation and Air Conditioning (HVAC) and Refrigeration Systems	2
3.4	Fans and blowers: Types, performance evaluation, efficient system operation, flow control strategies and energy conservation opportunities.	2
4	**Energy Efficiency in Lighting, DG systems and transformers (6hours)**	
4.1	Lighting Systems: Basic definitions- Lux, lumen and efficacy, Types of different lamps and their features, Energy efficient practices in lighting	2
4.2	DG Systems: Introduction, Energy efficiency opportunities in DG systems, Loading estimation	2
4.3	Transformers: Introduction, Losses in transformer, transformer Loading, Tips for energy savings in transformers	2
5	**Energy Efficient Technologies in Electrical Systems (7 hours)**	
5.1	Maximum demand controllers, automatic power factor controllers	1
5.2	Energy efficient motors, soft starters with energy saver	2

5.3	Variable speed drives, energy efficient transformers	2
5.4	Electronic ballast, occupancy sensors, energy efficient lighting controls	2

Reference Books

1) Guide book on General Aspects of Energy Management and Energy Audit by Bureau of Energy Efficiency, Government of India. Edition 2015

2) Guide book on Energy Efficiency in Electrical Utilities, by Bureau of Energy Efficiency, Government of India. Edition 2015

3) Guide book on Energy Efficiency in Thermal Utilities, by Bureau of Energy Efficiency, Government of India. Edition 2015

4) Handbook on Energy Audit & Environmental Management by Y P Abbi & Shashank Jain published by TERI. Latest Edition

5) S. C. Tripathy, " Utilization of Electrical Energy and Conservation" , McGraw Hill, 1991.

Important Links:

6) Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India. www.beeindia.gov.in.

7) Ministry of New and Renewable Energy (MNRE), Government of India. www.mnre.gov.in.

8) Central Pollution Control Board (CPCB), Ministry of Environment, Forest and Climate Change,

9) Government of India. www.cpcb.nic.in.

10) Energy Efficiency Services Limited (EESL). www.eeslindia.org.

11) Electrical India, Magazine on power and electrical products industry. www.electricalindia.in.

222EEE071	Electric Charging Systems for Electrical Vehicles	CATEGORY	L	T	P	CREDIT
		Interdisciplinary Elective	3	0	0	3

Preamble:

The course is aimed to provide an overview of the technological concepts and regulatory frameworks related to the charging systems of Electrical Vehicle

Course Outcomes:

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

CO 1	Analyze the working of different types of controlled rectifiers
CO 2	Analyze the working of different types of choppers
CO 3	Describe the energy storage mechanisms used for EV's
CO 4	Explain the various types of chargers used for EV's
CO 5	Explain the various charging standards for EV's

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing 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 nos	: 10 marks

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. Students should answer all questions. Part B will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question paper

APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M.TECH DEGREE EXAMINATION

MONTH &YEAR

Course code: 222EEE071

Course Name: Electric Charging Systems for Electric Vehicles

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

PART A

(Answer all questions. Each question carries 5 marks)

1. What is inverted mode of operation of the converter? Explain.
2. What is a two quadrant chopper? Explain.
3. Explain about the battery management systems used in EV.
4. Draw and explain the configuration of a level-1 charger.
5. Explain the CHAdeMo charging protocol for EV.

PART –B

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

6. Draw the circuit of 3 phase fully controlled rectifier with RLE load and explain the working for α=600 with necessary waveforms. Derive the expression for average output voltage.
7. 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.
8. Draw the circuit of 3 phase fully controlled rectifier with RL load and explain the working for α=60 degree with necessary waveforms. Derive the expression for average output voltage.
9. Explain the working of a Buck-Boost regulator, showing relevant waveforms and derive the expression for its output voltage.
10. Explain about Fuel cell based energy storage systems.
11. Explain the operation of level-3 battery charger with a neat circuit diagram.
12. Describe the various charging standards used for electric vehicles.

Syllabus

Module 1- AC-DC converters

Controlled Rectifiers (Single Phase) – Half-wave controlled rectifier with R load– 1-phase fully controlled bridge rectifier with R, RL and RLE loads (continuous conduction only) – Output voltage equation – Controlled Rectifiers (3-Phase) - 3-phase half-wave controlled rectifier with R load – 3-phase fully controlled converter with RLE load (continuous conduction, ripple free) – Output voltage equation-Waveforms for various triggering angles (analysis not required).

Module 2- DC-DC converters

DC-DC converters – Step down and Step up choppers – Single-quadrant, Two-quadrant and Four quadrant chopper – Pulse width modulation & current limit control in dc-dc converters. Switching regulators – Buck, Boost & Buck-boost –Operation with continuous conduction mode – Waveforms – Design (switch selection, filter inductance and capacitance).

Module 3- Energy storage

Energy Storage**:** Introduction to energy storage requirements in Electric Vehicles- Units of Battery Energy Storage - Capacity rate- Battery based energy storage systems, Types of battery- Lifetime and Sizing Considerations - Battery Charging, Protection, and Management Systems - Fuel Cell based energy storage systems- Supercapacitors- Hybridization of different energy storage devices.

Module 4- Charging infrastructure

On-board chargers, Electric Vehicle Supply Equipment (EVSE) - Grid to EVSE to On-board chargers to battery pack power flow block schematic diagrams – Types of charging stations - AC Level 1 & 2, DC - Level 3, Wireless charging. Plug-in Hybrid EV, V2G concept.

Module 5- Charging Standards

Charging Standards - SAE J1772, VDE-AR-E 2623-2-2, JEVS G105-1993, Types of Connectors - CHAdeMo, CCS Type1 and 2, GB/T - pin diagrams and differences, IEC 61851 - Electric vehicle conductive charging modes, IEC 61980- Electric vehicle wireless power transfer systems, IEC 62196 -AC Couplers Configuration, Combo AC DC Couplers and IS-17017 standards for EV charging.

COURSE PLAN

No	Topic	No. of Lectures
1	**AC-DC converters**	**8**
1.1	Controlled Rectifiers (Single Phase) – Half-wave controlled rectifier with R load– 1-phase fully controlled bridge rectifier with R, RL and RLE loads (continuous conduction only) –	2
1.2	Controlled Rectifiers (Single Phase) Output voltage equation – Controlled Rectifiers, Simple numeric problems	2
1.3	3-phase half-wave controlled rectifier with R load – 3-phase fully controlled converter with RLE load (continuous conduction, ripple free)	2
1.4	Controlled Rectifiers (Three Phase) Output voltage equation- Waveforms for various triggering angles (analysis not required). Simple numeric problems	2
2	**DC-DC converters**	**7**
2.1	Step down and Step up choppers – Single-quadrant, Two-quadrant and Four quadrant chopper	2
2.2	Pulse width modulation & current limit control in dc-dc converters.	1
2.3	Switching regulators – Buck, Boost & Buck-boost	2
2.4	Operations with continuous conduction mode – Waveforms – Design (switch selection, filter inductance and capacitance).	2
3	**Energy storage**	**9**
3.1	Introduction to energy storage requirements in Electric Vehicles	1
3.2	Units of Battery Energy Storage - Capacity rate-	1

3.3	Battery based energy storage systems, Types of battery-	1
3.4	Lifetime and Sizing Considerations	2
3.5	Battery Charging, Protection, and Management Systems	2
3.6	Fuel Cell based energy storage systems- Super capacitors-	1
3.7	Hybridization of different energy storage devices	1
4	**Charging infrastructure**	**8**
4.1	On-board chargers	1
4.2	Electric Vehicle Supply Equipment (EVSE) - Grid to EVSE to On-board chargers to battery pack.	1
4.3	Power flow block schematic diagrams	2
4.4	Types of charging stations - AC Level 1 & 2	1
4.5	Types of charging stations DC - Level 3,	1
4.6	Wireless charging.	1
4.7	Plug-in Hybrid EV, V2G concept	1
5	**Charging Standards**	**8**
5.1	SAE J1772, VDE-AR-E 2623-2-2, JEVS G105-1993,	2
5.2	Types of Connectors - CHAdeMo, CCS Type1 and 2,	1
5.3	GB/T - pin diagrams and differences,	1
5.4	IEC 61851 - Electric vehicle conductive charging modes	1
5.5	IEC 61980- Electric vehicle wireless power transfer systems,	1
5.6	IEC 62196 -AC Couplers Configuration, Combo AC DC Couplers	1
5.7	IS-17017 standards for EV charging.	1

Text books:

1. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.
2. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.
3. Mehrdad Ehsani, YimiGao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.
4. John G. Hayes, Electric powertrain, Wiley.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE072	**Design and installation of solar PV systems**	**INTERDISCIPLINARY ELECTIVE**	**3**	**0**	**0**	**3**

Preamble: This course provides an introduction to the artificial intelligence techniques and its applications to power system problems.

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

CO1	Describe various RES, estimate and select solar irradiance models
CO2	Demonstrate various MPPT techniques
CO3	Use appropriate inverters for PV applications
CO4	Design of the Standalone SPV System
CO5	Evaluate the life cycle cost of Grid connected PV system

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	3	-	1	2	3	2	-
CO2	3	2	3	2	3	2	-
CO3	3	1	2	2	3	1	1
CO4	3	3	3	3	3	3	3
CO5	3	3	3	3	3	3	2

Assessment Pattern

Bloom's Category	Continuous Assessment Tests	End Semester Examination
Remember		
Understand	20%	30%
Apply	40%	40%
Analyse	20%	30%
Evaluate	20%	
Create		

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

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

Test paper shall include minimum 80% of the syllabus.

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

Model Question paper

QP Code:
Name:
Reg No:

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
EIGHTH SEMESTER M. TECH DEGREE
EXAMINATION, MONTH & YEAR
Course Code: 222EEE072
Course Name: Design and installation of solar PV systems

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

PART A (5 x 5 = 25 Marks)

Answer all Questions. Each question carries 5 Marks

Q.no.	Module 1	Marks
1	Discuss the importance of intelligent techniques for the estimation of solar irradiance.	5
	Module 2	
2	Sketch and explain the P-V curve for two solar cells in parallel with non-identical V-I Characteristic.	5
	Module 3	
3	Enlist the advantages and disadvantages of string inverter as a grid tide inverter	5
	Module 4	
4	A PV Cell is to be emulated with a 24V battery with a 10ohm series resistance. Calculate the Fill Factor in this case	5

Module 5

5	Consider a situation where one enters into an annual maintenance contract (AMC) for a particular item. The annual maintenance amount is Rs.5000 for a 5 year period. If the rate of interest is 8% and the rate of inflation is 5%, what is the present worth of the AMC?	**5**

PART B (7 x 5 = 35 Marks)

Answer any five full questions. Each question carries 7 Marks

6 a.	Write the applications for the following solar radiation–measuring instruments: Pyrheliometer Sunshine recorder	**2**
b.	Draw the flowchart for an ANN model for estimation of solar irradiance using Backpropagation algorithm.	**5**
7.	A PV panel having an area of 1.5m2gives the following readings under standard test conditions. The short circuit current is 8A, the open circuit voltage is 40V, the voltage at peak power is36.5V and the current at peak power is 7A. The fill factor of the PV panel is found to be 0.72. Calculate the efficiency of the panel.	**7**
8.	Derive the expression for impedance seen by the solar cell utilizing the volt-sec and amp-sec balance concept, when a Buck Converter is used for MPPT operation. Sketch the operating region with Load line concept in I-V curve of Solar cell, while using Buck Converter for MPPT operation.	**7**
9 a.	The present cost of a solar panel is Rs 2000. If the interest rate is 8% and the inflation rate is 5% then how much must one save today in order to purchase the solar panel 5 years from now?	**3**
b	Explain the steps involved in design of standalone solar PV system	**4**
10	Draw the functional block diagram of a 3 phase grid connected Solar P V system under d-q frame control. Explain each section in details.	**7**
11.	Derive the expression for impedance seen by the solar cell utilizing the volt-sec and amp-sec balance concept, when a Buck Converter is used for MPPT operation. Sketch the operating region with Load line concept in I-V curve of Solar cell, while using Buck Converter for MPPT operation	**7**
12a.	What are the advantages of supercapacitors and fuel cells compared to conventional battery energy storage system.	**4**
b.	Explain Depth of Discharge, life cycle of battery and round-trip efficiency	**3**

No.	Syllabus
1	**Introduction to various RES, Measurement and Estimation of Solar Irradiance (10 hours)**
	Need for Renewable Energy Sources- Potential Renewable Energy Sources (RES) for Power Generation- Solar Energy,Wind Energy,Biomass Energy, Small Hydropower Plants Hydropower Project Classification, Geothermal Energy and Its Potential in India, Wave Energy, Tidal Energy-Government Initiatives for Solar Photovoltaic Systems.(2hrs) Measurement and Estimation of Solar Irradiance: The Solar Irradiance Spectrum, Solar Constant and Solar Irradiance, Depletion of Solar Radiation by the Atmosphere, Factors Affecting the Availability of Solar Energy on a Collector Surface, Radiation Instruments, Solar Irradiance Components, Instruments Used Detectors for Measuring Radiation, Measuring Diffuse Radiation (4Hrs) Mathematical Models of Solar Irradiance, Estimation of Global Irradiance,Diffuse Irradiance, Regression Models, Intelligent Modeling, Fuzzy Logic–Based Modeling of Solar Irradiance, Artificial Neural Network for Solar Energy Estimation, Generalized Neural Model(4hrs)
2	**Fundamentals of Solar Photovoltaic Cells, MPPT techniques, Modules, and Arrays (10 hours)**
	Solar PV Fundamentals: The Solar Cell, Material for the Solar Cell, PV cell characteristics and equivalent circuit, Model of PV cell, Short Circuit, Open Circuit and peak power parameters, Datasheet study, Cell efficiency, Effect of temperature, Temperature effect, Solar PV Modules, Bypass Diodes, Hot Spot Formation, Fill Factor, Solar Cell Efficiency and Losses, Methods to Increase Cell Efficiency. Standard Test Conditions (STC) of the PV Cell, Factors Affecting PV Output-Tilt Angles, Partial Shading, Effect of Light Intensity, PV Module Testing and Standards,Quality Certification, Standards, and Testing for Grid-Connected Rooftop Solar PV Systems/Power Plants (4Hrs) Maximum Power Point Tracking Techniques and Charge Controllers: MPPT and Its Importance, MPPT Techniques- Curve-Fitting Technique, Fractional Short-Circuit Current (FSCC) Technique, Fractional Open-Circuit Voltage Technique, Direct Method- Perturb and Observe, Incremental Conductance Method (4Hrs) Comparison of Various MPPT Techniques, Charge Controllers and MPPT Algorithms, Modeling and of PV System with Charge Controller (2Hrs)
3	**Converter Design for SPV System (6 hours)**

	DC to DC Converters- Classification of DC-to-DC Converters- Buck converter, Boost converter, Buck–boost converter- Uses **DC to AC Converters (inverters):** Classification of Inverters- Classification based on output voltage: Square wave inverters, Modified square wave inverters, Pure sine wave inverters. Voltage source inverter: half bridge and full bridge -Current source inverter Multilevel inverter: Diode clamped, Flying capacitor- Applications Photovoltaic (PV) Inverter-incorporating MPPT-Standalone inverter- Grid Tied inverter-string inverters, solar microinverters, and centralized inverters
4	**Energy Storage for PV Applications, Design of the Standalone SPV System (7 hours)**
	Batteries - Capacity, C-rate, Efficiency, Energy and power densities, Battery selection, Other energy storage methods, Battery Storage System, Functions Performed by Storage Batteries in a PV System-Types of Batteries- Lead-Acid Batteries, Nickel-Cadmium (Ni-Cd) Batteries, Nickel-Metal Hydride (Ni-MH) Batteries, Lithium Ion Batteries etc. Installation, Operation, and Maintenance of Batteries, System Design and Selection Criteria for Batteries, Effect of DoD Disposal of Batteries, Super Capacitors, Fuel Cells **Mounting Structure:** Assessment of Wind Loading on PV Array, Types of Module Mounting Systems, PV Array Row Spacing, Standards for Mounting Structures **Design of the Standalone SPV System**: Sizing of the PV Array- Sizing of the Battery Block-Design of the Battery Charge Controller- Design of the Inverter, Sizing PV for applications without batteries, PV system design, Load profile, Days of autonomy and recharge, Battery size, PV array size, Direct PV-battery connection, Charge controller
5	**Grid-Connected PV Systems, Life Cycle Cost Analysis (7 hours)**
	Grid connection principle, PV to grid topologies, (Basic concept of d-q theory) Complete 3ph grid connection, 1ph d-q controlled grid connection (Basic treatment only), SVPWM, Life cycle costing, Growth models, Annual payment and present worth factor, LCC with examples- Life Cycle Cost Analysis- Case Study based on Difference in Power Consumption Bill, Payback Period Calculation, Comparison of PV and Conventional Electricity Costs

Syllabus and Corse Plan

No.	Topic	No. of Lectures
1		
1.1	Introduction to various RES-Solar Energy, Wind Energy, Biomass Energy, Small Hydropower Plants Hydropower Project Classification, Geothermal Energy and Its Potential in India	2
1.2	The Solar Irradiance Spectrum, Solar Constant and Solar Irradiance, Depletion of Solar Radiation by the Atmosphere, Factors Affecting the Availability of Solar Energy on a Collector Surface,	2

1.3	Radiation Instruments, Solar Irradiance Components, Instruments Used Detectors for Measuring Radiation, Measuring Diffuse Radiation.	2
1.4	Mathematical Models of Solar Irradiance, Estimation of Global Irradiance, Diffuse Irradiance, Regression Models, Intelligent Modeling	1
1.5	Fuzzy Logic–Based Modeling of Solar Irradiance	1
1.6	Artificial Neural Network for Solar Energy Estimation, Generalized Neural Model	2
2		
2.1	The Solar Cell, Material for the Solar Cell, PV cell characteristics and equivalent circuit, Model of PV cell, Short Circuit, Open Circuit and peak power parameters, Datasheet study, Cell efficiency, Effect of temperature	1
2.2	Temperature effect, Solar PV Modules, Bypass Diodes, Hot Spot Formation, Fill Factor, Solar Cell Efficiency and Losses, Methods to Increase Cell Efficiency.	1
2.3	Standard Test Conditions (STC) of the PV Cell, Factors Affecting PV Output-Tilt Angles, Partial Shading, Effect of Light Intensity,	1
2.4	PV Module Testing and Standards, Quality Certification, Standards, and Testing for Grid-Connected Rooftop Solar PV Systems/Power Plants	1
2.5	MPPT and its Importance, MPPT Techniques- Curve-Fitting Technique, Fractional Short-Circuit Current (FSCC) Technique,	2
2.6	Fractional Open-Circuit Voltage Technique, Direct Method- Perturb and Observe, Incremental Conductance Method	2
2.7	Comparison of Various MPPT Techniques, Charge Controllers and MPPT Algorithms, Modeling and of PV System with Charge Controller	2
3		
3.1	Classification of DC-to-DC Converters- Buck converter, Boost converter, Buck–boost converter- Uses	1
3.2	Classification Inverters based on output voltage: Square wave inverters, Modified square wave inverters, Pure sine wave inverters.	1
3.3	Voltage source inverter: half bridge and full bridge -Current source inverter	1
3.4	Multilevel inverter: Diode clamped, Flying capacitor- Applications	1
3.5	Photovoltaic (PV) Inverter-incorporating MPPT-Standalone inverter- Grid Tied inverter-string inverters, solar microinverters, and centralized inverters	2
4		

4.1	Batteries - Capacity, C-rate, Efficiency, Energy and power densities, Battery selection, Other energy storage methods	1
4.2	Battery Storage System, Functions Performed by Storage Batteries in a PV System-Types of Batteries- Lead-Acid Batteries, Nickel-Cadmium (Ni-Cd) Batteries, Nickel-Metal Hydride (Ni-MH) Batteries, Lithium Ion Batteries etc.	1
4.3	Installation, Operation, and Maintenance of Batteries, System Design and Selection Criteria for Batteries, Effect of DoD Disposal of Batteries, Super Capacitors, Fuel Cells	1
4.4	Assessment of Wind Loading on PV Array, Types of Module Mounting Systems, PV Array Row Spacing, Standards for Mounting Structures	2
4.5	Sizing of the PV Array- Sizing of the Battery Block-Design of the Battery Charge Controller- Design of the Inverter, Sizing PV for applications without batteries, PV system design, Load profile, Days of autonomy and recharge, Battery size, PV array size, Direct PV-battery connection, Charge controller	2
5		
5.1	Grid connection principle, PV to grid topologies, Complete 3ph grid connection, 1ph d-q controlled grid connection, SVPWM,	2
5.2	Life cycle costing, Growth models, Annual payment and present worth factor	2
5.3	LCC with examples- Life Cycle Cost Analysis- Case Study based on Difference in Power Consumption Bill	2
5.4	Payback Period Calculation, Comparison of PV and Conventional Electricity Costs	1

Text Books

1. Jamil, Majid, M Rizwan, D Kothari. *Grid Integration of Solar Photovoltaic Systems*. CRC Press, 2017.
2. Solar PV System Design _ NPTEL Lecture L Umanand

References

1. Godfrey Boyle: Renewable energy, Power for a sustainable future. Oxford University press U.K

2. D. Y. Goswami, F. Kreith and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis, Philadelphia, 2000.

3. Mukherjee and Thakur: Photovoltaic Systems Analysis and Design, PHI, Eastern Economy Edition, 2012.

4. Solanki: Solar Photovoltaics- Fundamentals, Technologies and Applications, PHI, Eastern Economy Edition, 2012

5. B. H. Khan, Non-Conventional Energy Resources, 2nd edition, TMH 2013

6. O'Hayre, R.P., S. Cha, W. Colella, F.B.Prinz, Fuel Cell Fundamentals, Wiley, NY (2006).

7. Liu, H., Principles of fuel cells, Taylor & Francis, N.Y. (2006).

8. Kreith F., Goswami D.Y., Energy Management and Conservation, CRC Press 2008

9. Kothari: Renewable Energy Sources and Emerging Technologies, PHI, Eastern Economy Edition, 2012

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222LEE100	RENEWABLE ENERGY AND DRIVES LABORATORY	Laboratory 2	0	0	2	1

Preamble: To impart practical knowledge about the power electronic circuits with renewable Energy and Electric Drives

Prerequisite: Fundamentals of power electronics and electric drives

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

CO 1	Design and Demonstrate power electronic circuits, drives, renewable energy circuits using microcontrollers /DSP /FPGA
CO 2	Solve engineering problems applied to power electronic applications
CO 3	Examine the performance of various power electronic converters and drives through simulation software like MATLAB, PROTEUS, PSIM, SCILAB, ORCAD etc
CO 4	Design and implement closed loop control schemes for power electronic converters, power quality circuits using state space averaging and compensators/ PID controllers.
CO 5	Analyse the experiment efficiently as an individual and as a member in the team to solve various problems.
CO 6	Build proper reports of experiments that clearly illustrate the concepts, design and simulation & experimental results

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

Assessment Pattern

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 will 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%

Syllabus

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

Mandatory experiment

Microcontroller based PWM generation and control of the PWM duty cycle with ADC port of the microcontroller

Hardware Experiments (Minimum five experiments)

1. Study of solar PV characteristics, effect of tilt and azimuth on power output of the panel
2. MPPT realization (open circuit voltage/short circuit current) using buck/boost/buck-boost converter
3. MPPT realization (Perturb & Observe/incremental conductance) using buck/boost/buck-boost converter
4. Study of effect of shading on series/parallel connected solar panels and the effect of blocking and bypass diodes
5. Study of Wind turbine/Wind turbine emulator
6. MPPT of Wind turbine/wind emulator
7. Study and measurement of harmonic pollution by power electronics loads using power quality analyser/Spectrum analyser/DSO
8. Speed control of converter/chopper fed DC motor drive using PWM generation block in microcontroller/DSP/FPGA
9. Single phase sine-triangle PWM/SVPWM generation using Microcontroller/DSP/FPGA
10. Single phase VSI feeding RL load using sine-triangle PWM with proper isolation and fault protection
11. Single phase Hysteresis current control of VSI feeding an RL load
12. VSI fed three phase induction motor drive using open loop V/f control by Microcontroller/DSP
13. Speed control of BLDC motor using microcontroller/FPGA/DSP
14. Speed control of PMSM motor using microcontroller/FPGA/DSP
15. Design and realization of closed loop control of buck/boost/buck-boost converters using Microcontroller
16. Design and realisation of snubber and heat sink for chopper fed DC drive
17. Design and realisation of switching regulator based charging circuit for lead acid/lithium ion batteries

Simulation (Minimum five simulation studies)

1. State space Modeling and Simulation of starting (free acceleration) characteristics of 3-phase induction motor
2. State space Modeling and Simulation of Vector control of 3-phase induction motor

3. Simulation of Direct Torque Control of 3-phase induction motor
4. State space Modeling and Simulation of PMSM
5. Simulation of vector control of PMSM
6. State space Modeling and Simulation of BLDC motor drive
7. Simulation of STATCOM & DSTATCOM
8. Simulation of Active Power Filter/DVR
9. Simulation of TCSC/UPQC
10. State space modeling and simulation of single phase/three phase PWM rectifier
11. Design and simulation of closed loop control of chopper fed DC drives
12. Simulation of a separately excited DC motor drive with closed loop control for four quadrant operation
13. Simulation of MPPT tracking of solar modules (open circuit voltage/short circuit current) using buck/boost/buck-boost converter
14. Simulation of MPPT tracking of solar modules (Perturb & Observe/ incremental conductance) using buck/boost/buck-boost converter
15. Simulation of wind emulator
16. Simulation of MPPT tracking of wind turbine - any scheme
17. Simulation of charging and protection circuit for lead acid/lithium ion batteries with three phase PWM rectifier and switching regulator

COURSE CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222PAE100	MINI PROJECT	PROJECT	0	0	4	2

Mini project can help to strengthen the understanding of student's fundamentals through application of theoretical concepts and to boost their skills and widen the horizon of their thinking. The ultimate aim of an engineering student is to resolve a problem by applying theoretical knowledge. Doing more projects increases problem solving skills.

The introduction of mini projects ensures preparedness of students to undertake dissertation. Students should identify a topic of interest in consultation with PG Programme Coordinator that should lead to their dissertation/research project. Demonstrate the novelty of the project through the results and outputs.The progress of the mini project is evaluated based on three reviews, two interim reviews and a final review. A report is required at the end of the semester.

Evaluation Committee - Programme Coordinator, One Senior Professor and Guide.

Sl. No	Type of evaluations	Mark	Evaluation criteria
1	Interim evaluation 1	20	
2	Interim evaluation 2	20	
3	Final evaluation by a Committee	35	Will be evaluating the level of completion and demonstration of functionality/ specifications, clarity of presentation, oral examination, work knowledge and involvement
4	Report	15	the committee will be evaluating for the technical content, adequacy of references, templates followed and permitted plagiarism level(not more than 25%)
5	Supervisor/Guide	10	
	Total Marks	100	

SEMESTER III

SEMESTER III

Slot	Course code	Courses	Marks		L-T-P	Hours	Credit
			CIE	ESE			
TRACK 1							
A*	223MxxXXX	MOOC	To be completed successfully		--	--	2
B	223AGEXXX	Audit Course	40	60	3-0-0	3	-
C	223Ixx100	Internship	50	50	--	--	3
D	223Pxx100	Dissertation Phase 1	100	--	0-0-17	17	11
TRACK 2							
A*	223MxxXXX	MOOC	To be completed successfully		--	--	2
B	223AGEXXX	Audit Course	40	60	3-0-0	3	-
C	223Ixx100	Internship	50	50	---	--	3
D	223Pxx001	Research Project Phase1	100	--	0-0-17	17	11
TOTAL			**190**	**110**		**20**	**16**

Teaching Assistance: 6 hours

*MOOC Course to be successfully completed before the commencement of fourth semester (starting from semester 1).

AUDIT COURSE

AUDIT COURSE						
SLOT	**SL NO**	**COURSE CODE**	**COURSE NAME**	**L-T-P**	**HOURS**	**CREDIT**
B	1	223AGE100	ACADEMIC WRITING	3-0-0	3	-
	2	223AGE001	ADVANCED ENGINEERING MATERIALS	3-0-0	3	-
	3	223AGE002	FORENSIC ENGINEERING	3-0-0	3	-
	4	223AGE003	DATA SCIENCE FOR ENGINEERS	3-0-0	3	-
	5	223AGE004	DESIGN THINKING	3-0-0	3	-
	6	223AGE005	FUNCTIONAL PROGRAMMING IN HASKELL	3-0-0	3	-
	7	223AGE006	FRENCH LANGUAGE (A1 LEVEL)	3-0-0	3	-
	8	223AGE007	GERMAN LANGUAGE (A1 LEVEL)	3-0-0	3	-
	9	223AGE008	JAPANESE LANGUAGE (N5 LEVEL)	3-0-0	3	-
	10	223AGE009	PRINCIPLES OF AUTOMATION	3-0-0	3	-
	11	223AGE010	REUSE AND RECYCLE TECHNOLOGY	3-0-0	3	-
	12	223AGE011	SYSTEM MODELING	3-0-0	3	-
	13	223AGE012	EXPERT SYSTEMS	3-0-0	3	-

MOOC COURSES

The MOOC course shall be considered only if it is conducted by the agencies namely AICTE/NPTEL/SWAYAM or NITTTR. The MOOC course should have a minimum duration of 8 weeks and the content of the syllabus shall be enough for at least 40 hours of teaching. The course should have a proctored/offline end semester examination. The students can do the MOOC according to their convenience, but shall complete it by third semester. The list of MOOC courses will be provided by the concerned BoS if at least 70% of the course content match with the area/stream of study. The course shall not be considered if its content has more than 50% of overlap with a core/elective course in the concerned discipline or with an open elective.

MOOC Course to be successfully completed before the commencement of fourth semester (starting from semester 1). A credit of 2 will be awarded to all students whoever successfully completes the MOOC course as per the evaluation pattern of the respective agency conducting the MOOC.

TEMPLATE FOR SYLLABUS

CODE 223AGE100	ACADEMIC WRITING	CATEGORY	L	T	P	CREDIT
		AUDIT COURSE	3	0	0	NIL

Preamble: Learning academic writing sharpens minds, teaches students how to communicate, and develops their thinking capacities and ability to understand others. Writing is thinking, and every student deserves to be a strong thinker. It can also make them think more carefully about what they write. Showing work to others can help to foster a better culture of learning and sharing among students. It also gives students a sense of how they are contributing to the body of work that makes up an academic subject.

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

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

CO 1	Understand the principles of scientific/ academic writing
CO 2	Analyse the technique of scientific writing from the reader's perspective
CO 3	Apply the concepts of setting expectations and laying the progression tracks
CO 4	Evaluate the merits of a title, abstract , introduction, conclusion and structuring of a research paper
CO 5	Justify the need using a project proposal or a technical report
CO 6	Prepare a review paper, an extended abstract and a project proposal

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Course based task : 15 marks
Seminar/Quiz : 15 marks
Test paper, 1 no. : 10 marks
Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: 60 marks

The examination will be conducted by the respective College. The examination willbe for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any Vive. Each question can carry 12 marks.

Model Question paper

	SET1	**Total Pages:**
Reg No.:_______________		Name:___________________________
APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY THIRD SEMESTER M.TECH DEGREE EXAMINATION, MARCH 2024		
Course Code: 223AGE100		
Course Name: Academic Writing		
Max. Marks: 60		Duration: 2.5 Hours
Answer any five full questions, each carries 12 marks.		
1 a)	Make clear-cut distinctions between 6 factors that take their toll on readers' memory.	6
1 b)	How can you sustain the attention of the reader to ensure continuous reading?	6
2 a)	What are the different methods by which you can create expectations in the reader?	6
2 b)	Give an account of the topic and non-topic based progression schemes.	6
3 a)	Bring out the differences between an abstract and the introduction of a research paper.	8
3 b)	How are the title of the research paper and its structure related?	4
4	What are 7 principles for including visuals in your research paper. What are the recommended constituents of a conclusion segment of a research paper?	12

5	Give a detailed description of the process and contents of a project proposal for funding.	12
6 a)	What are the contexts recommended for choosing between active and passive voices in technical writing?	8
6 b)	What are the different visual forms that are relevant in a research paper and how do you choose them?	4
7	Give the design of a research paper with the purposes each part serves.	12
****		

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

Syllabus:

CODE 223AG E100	**ACADEMIC WRITING**	**Audit**
Module No.	Topics in a module	Hours
1	Fundamentals of Academic writing from a reader's perspective: acronyms, synonyms, pronouns, disconnected phrases, background ghettos, abusive detailing, cryptic captions, long sentences : all that take their toll on readers' memory.	6
2	Fluid reading & reading energy consumption: setting expectations and laying Progression tracks; Reading energy consumption	6
3	How to write the Title, abstract, introduction ; Structure the writing with headings & subheadings	6
4	Visuals: Resources, Skills, and Methods; Conclusion; References; Bibliography; Grammar in technical writing	6
5	Techniques of writing: An extended abstract, a project proposal, a research paper, a technical report.	6

Course Plan:

No	Topic	No. of Lectures
1	Fundamentals of Academic writing from a reader's perspective: acronyms, synonyms, pronouns, disconnected phrases, background ghettos, abusive detailing, cryptic captions, long sentences all take their toll on readers' memory.	
1.1	The Reading tool-kit to reduce memory required; reduce reading time	1
1.2	Acronyms, Pronouns, Synonyms; Background, broken couple, words overflow	1
1.3	Sustain attention: Keep the story moving forward; Twists, shouts, Pause to clarify, recreate suspense	2

1.4	Keep the reader motivated: Fuel and meet Expectations; Bridge knowledge gap: ground level; Title words; Just In Time to local background	2
2	Fluid reading & reading energy consumption: setting expectations and laying Progression tracks; Reading energy consumption	
2.1	Setting expectations of the reader from Grammar, from theme	1
2.2	Progression tracks for fluid reading: Topic & stress; topic and non topic based progression tracks; pause in progression	2
2.3	Detection of sentence fluidity problems: No expectations/ Betrayed expectations	2
2.4	Controlling reading energy consumption: the energy bill; Energy fuelling stations: Pause	1
3	How to write the Title, abstract, introduction ; Structure the writing with headings & subheadings	
3.1	Title: Face of the paper: Techniques, Qualities & Purpose of title; Metrics	1
3.2	Abstract: Heart of the paper: 4 parts; coherence; tense of verbs, precision; purpose & qualities of the abstract; Metrics	2
3.3	Structure: Headings & sub-headings: Skeleton of the paper: principles for a good structure; Syntactic rules; Quality & Purpose of structures; Metrics	1
3.4	Introduction: Hands of the paper: Start, finish; scope, definitions; answers key reader questions; As a personal active story; Traps, qualities; Metrics	2
4	Visuals: Resources, Skills, and Methods; Conclusion; References; Bibliography; Grammar in technical writing	
4.1	Visuals as the voice of your paper: principles; purpose & qualities of visuals; metrics	2
4.2	Conclusion: contents; purpose, quality; metrics; Abstracts Vs. Conclusion; examples, counter-examples	1
4.3	References, Bibliography: Styles, punctuation marks, quotes, citations	1
4.4	Grammar in Technical writing: Articles, Syntax, Main and subordinate clauses; Active & passive voices; some commonly made mistakes in technical writing.	2
5	Techniques of writing: An extended abstract, a project proposal, a research paper, a technical report.	
5.1	Extended abstract: abstract and keywords, introduction and objective, method, findings and argument, conclusion and suggestions and references.	1
5.2	Project Proposal:Types, executive summary, background including status, objectives, solution, milestones, deliverables, timelines, resources, budgeting, conclusion	2
5.3	Research paper: writing an overview article: provide a comprehensive foundation on a topic; explain the current state of knowledge; identify gaps in existing studies for potential future research; highlight the main methodologies and research techniques	2

5.4	Writing Technical Reports: Title page; Summary; Table of contents; Introduction; Body; Figures, tables, equations and formulae; Conclusion; Recommendations.	1
		30

Reference Books

1. SCIENTIFIC WRITING 2.0 A Reader and Writer's Guide: Jean-Luc Lebrun, World ScientiVic Publishing Co. Pte. Ltd., 2011

2. How to Write and Publish a ScientiVic Paper: Barbara Gastel and Robert A. Day, Greenwood publishers, 2016

3. Grammar, Punctuation, and Capitalisation; a handbook for technical writers and editors. www.sti.nasa.gov/publish/sp7084.pdf www.sti.nasa.gov/sp7084/contents.html

4. Everything You Wanted to Know About Making Tables and Figures. http://abacus.bates.edu/%7Eganderso/biology/resources/writing/ HTWtableVigs.html

223AGE001	ADVANCED ENGINEERING MATERIALS	CATEGORY	L	T	P	CREDIT
		AUDIT COURSE	3	0	0	-

Preamble: This course is designed in a way to provide a general view on typically used advanced classes of engineering materials including metals, polymers, ceramics, and composites.

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

CO 1	Analyse the requirement and find appropriate solution for use of materials.
CO 2	Differentiate the properties of polymers, ceramics and composite materials.
CO 3	Recognize basic concepts and properties of functional materials.
CO 4	Comprehend smart and shape memory materials for various applications.
CO 5	Appraise materials used for high temperature, energy production and storage applications.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	**End Semester Examination**
Understand	60%
Apply	20%
Analyse	20%

Mark distribution

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

Continuous Internal Evaluation Pattern: 40 marks

Course based task : 15 marks
Seminar/Quiz : 15 marks
Test paper, 1 no. : 10 marks
Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: 60 marks

The examination will be conducted by the respective College. The examination willbe for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any Vive. Each question can carry 12 marks.

Model Question paper

AUDIT COURSE

223AGE001 - ADVANCED ENGINEERING MATERIALS

(Answer any five questions. Each question carries 12 Marks)

1.	a) State the relationship between material selection and processing.	**5**
	b) Write about the criteria for selection of materials with respect to the cost and service requirements for engineering applications.	**7**
2.	a) Differentiate thermosetting and thermoplastics with suitable examples.	**5**
	b) Briefly discuss about the properties and applications of polymer nano composite materials.	**7**
3.	a) Write about the potential application areas of functionally graded materials.	**5**
	b) With a neat sketch describe any one processing technique of functionally graded materials.	**7**
4.	a) “Smart materials are functional”? Justify the statement.	**5**
	b) Explain the terms electrostriction and magnetostriction with its application.	**7**

5.	a) What are the factors influencing functional life of components at elevated temperature?	**5**
	b) What are super alloys and what are their advantages?	**7**
6	a) What is a shape memory alloy? What metals exhibit shape memory characteristics?	**4**
	b) Explain about the detection capabilities and uses of pyroelectric sensors.	**8**
7	a) Differentiate between conventional batteries and fuel cells.	**4**
	b) Explain the construction and working of a Li-ion battery.	**8**

Syllabus

Module	Content	Hours	Semester Exam Marks (%)
I	Requirements / needs of advanced materials. Classification of materials, Importance of materials selection, Criteria for selection of materials; motivation for selection, cost basis and service requirements. Relationship between materials selection and processing.	**5**	**20**
II	Classification of non-metallic materials. Polymer, Ceramics: Properties, processing and applications. Nano Composites - Polymer nanocomposites (PNCs), Processing and characterisation techniques – properties and potential applications.	**7**	**20**
III	Functionally graded materials (FGMs), Potential Applications of FGMs, classification of FGMs, processing techniques. limitations of FGMs.	**6**	**20**
IV	Smart Materials: Introduction, smart material types - pyroelectric sensors, piezoelectric materials, electrostrictors and magnetostrictors, shape memory alloys – associated energy stimulus and response forms, applications.	**5**	**20**
V	High Temperature Materials: super alloys – main classes, high temperature properties of superalloys, applications. Energy Materials: materials for batteries.	**7**	**20**

Course Plan

No	Topic	No. of Lectures
1	**Selection of materials for engineering applications**	
1.1	Benefits of advanced materials, classification of materials, importance of materials selection	2
1.2	Selection of materials for different properties, strength, toughness, fatigue and creep	1
1.3	Selection for surface durability, corrosion and wear resistance	1
1.4	Relationship between materials selection and processing	1
2	**Classification of non-metallic materials & nano composites**	
2.1	Rubber: properties, processing and applications.	1
2.2	Plastics: thermosetting and thermoplastics, applications and properties.	2
2.3	Ceramics: properties and applications.	1
2.4	Introduction to nano composites, classification	1
2.5	Processing and characterisation techniques applicable to polymer nanocomposites.	2
3	**Functionally graded materials**	
3.1	General concept, Potential Applications of FGMs	2
3.2	Classification of FGMs	1
3.3	FGMs processing techniques: powder metallurgy route, melt-processing route	2
3.4	Limitations of FGMs	1
4	**Smart materials**	
4.1	Introduction to smart materials, types	1
4.2	Pyroelectric sensors-material class, stimulus, detection capabilities and uses	1
4.3	Piezoelectric materials- material class, stimulus, sensing and actuating applications	1
4.4	Electrostrictors and magnetostrictors - material class, stimulus, micro positioning capabilities and applications	1
4.5	Shape memory alloys (SMAs) - material class, stimulus, temperature sensing and high strain responses, applications.	1
5	**High Temperature Materials and Energy Materials**	
5.1	Characteristics of high-temperature materials, superalloys as high-temperature materials	1
	superalloys - properties and applications	2
5.2	Introduction to lithium-ion battery (LIBs), operating mechanisms and applications	2
5.3	Introduction to Zn-based battery system, types and existing challenges	2

Reference Books

1. DeGarmo et al, “Materials and Processes in Manufacturing”, 10th Edition, Wiley, 2008.
2. R.E. Smallman and A.H.W. Ngan, Physical Metallurgy and Advanced Materials, Seventh Edition, Butterworth-Heinemann, 2007
3. Vijayamohanan K. Pillai and Meera Parthasarathy, “Functional Materials: A chemist’s perspective”, Universities Press Hyderabad (2012).
4. M.V. Gandhi, B.S. Thompson: Smart Materials and Structures, Chapman & Hall, 1992.
5. G. W. Meetham and M. H. Van de Voorde, Materials for High Temperature Engineering Applications (Engineering Materials) Springer; 1 edition (May 19, 2000)
6. Inderjit Chopra, Jayant Sirohi, “Smart Structures Theory”, Cambridge University Press, 2013

223AGE003	DATA SCIENCE FOR ENGINEERS	CATEGORY	L	T	P	CREDIT
		AUDIT COURSE	3	0	0	0

Preamble: This course covers essentials of statistics and Linear Algebra and how to prepare the data before processing in real time applications. The students will be able to handle missing data and detection of any outliers available in the dataset. This course explores data science, Python libraries and it also covers the introduction to machine learning for engineers.

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

CO 1	Study Data Science Concepts and statistics
CO 2	Demonstrate Understanding of Mathematical Foundations needed for Data Science
CO 3	Understand Exploratory analysis and Data Visualization and Preprocessing on given dataset
CO 4	Implement Models such as Naive Bayes, K-Nearest Neighbors, Linear and Logistic Regression
CO 5	Build real time data science applications and test use cases

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO7
CO 1	2		2			2	
CO 2	2		2	1		2	
CO 3	2		2	2	2	2	
CO 4	2		2	2	3	2	
CO 5	2		2	3	3	3	2

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Course based task (Project/Assignments/Simulations/Case studies): 15 marks

Seminar/Quiz : 15 marks

Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:**60 marks**

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 mark.

Syllabus

Module	**Content**	**Hours**	**Semester Exam Marks (%)**
I	**Statistics for Data science** Probability: Basic concepts of probability, conditional probability, total probability, independent events, Bayes' theorem, random variable, Population, Sample, Population Mean, Sample Mean, Population Distribution, Sample Distribution and sampling Distribution, Mean, Mode, Median, Range, Measure of Dispersion, Variance, Standard Deviation, Gaussian/Normal Distribution, covariance, correlation.	**6**	**20**
II	**Linear Algebra** Vectors and their properties, Sum and difference of Vectors, distance between Vectors, Matrices,Inverse of Matrix, Determinant of Matrix, Trace of a Matrix, Dot Product, Eigen Values, Eigen Vectors, Single Value Decomposition	**6**	**20**
III	**Hypothesis Testing** Understanding Hypothesis Testing, Null and Alternate Hypothesis, Non-directional Hypothesis, Directional Hypothesis Critical Value Method, P-Value Method, Types of Errors-Type1 Error,Type2 Error, Types of Hypothesis Test Z Test, Chi-Square	**6**	**20**

IV	**Exploratory Data Analysis** Data Collection –Public and Private Data, Data Cleaning-Fixing Rows and Columns, Missing Values, Standardizing values, invalid values, filtering data, Data-Integration,Data-Reduction,Data Transformation	**6**	**20**
V	**Machine Learning and Python for Data Science** Python Data structures-List, Tuple, Set, Dictionary, Pandas, Numpy, Scipy, Matplotlib, Machine Learning-Supervised Machine Learning, Unsupervised Machine Learning,Regression, Classification, Naïve-Bayes	**6**	**20**

Course Plan

No	Topic	No. of Lectures
1	**Statistics for Data science**	
1.1	Probability: Basic concepts of probability, conditional probability, total probability	1
1.2	independent events, Bayes' theorem, random variable, Population	1
1.3	Sample, Population Mean, Sample Mean, Population Distribution	1
1.4	Sample Distribution and sampling Distribution, Mean, Mode, Median, Range, Propositional logic and predicate logic	1
1.5	Measure of Dispersion, Variance, Standard Deviation	1
1.6	Gaussian/Normal Distribution, covariance, correlation.	1
2	**Linear Algebra**	
2.1	Vectors and their properties,	1
2.2	Sum and difference of Vectors, distance between Vectors	1
2.3	Matrices,Inverse of Matrix,	2
2.4	Determinant of Matrix, Trace of a Matrix, Dot Product, Eigen Values, Eigen Vectors, Single Value Decomposition	2
3	**Hypothesis Testing**	
3.1	Understanding Hypothesis Testing, Null and Alternate Hypothesis	1
3.2	Non-directional Hypothesis, Directional Hypothesis Critical Value Method, P-Value Method,	2
3.3	Types of Errors-Type1 Error,Type2 Error,	1
3.4	Types of Hypothesis Test Z Test, Chi-Square,	2
4	**Exploratory Data Analysis**	
4.1	Data Collection –Public and Private Data	1
4.2	Data Cleaning-Fixing Rows and Columns	1
4.3	Missing Values	1
4.4	Standardizing values	1
4.5	Invalid values, filtering data	1
4.6	Data Integration, Data Reduction, Data Transformation	1

5	**Machine Learning and Python for Data Science**	
5.1	Python Data structures-List, Tuple, Set,	1
5.2	Dictionary, Pandas, Numpy, Matplotlib	2
5.3	Machine Learning-Supervised Machine Learning, Unsupervised Machine Learning	1
5.4	Regression, Classification	1
5.5	Naïve-Bayes	1

Reference Books

1. Python Data Science Handbook. Essential Tools for Working with Data, Author(s): Jake VanderPlas, Publisher: O'Reilly Media, Year: 2016
2. Practical Statistics for Data Scientists: 50 Essential Concepts, Author(s): Peter Bruce, Andrew Bruce, Publisher: O'Reilly Media, Year: 2017
3. Practical Linear Algebra for Data Science, by Mike X Cohen, Released September 2022, Publisher(s): O'Reilly Media, Inc.
4. Data Science from Scratch 'by Joel Grus, Released, April 2015, Publisher(s): O'Reilly Media, Inc.
5. Hands-On Exploratory Data Analysis with Python, by Suresh Kumar Mukhiya, Usman Ahmed, Released March 2020,Publisher(s): Packt Publishing

SET1 **Total Pages:**

Reg No.:__ Name:___________________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

THIRD SEMESTER M.TECH DEGREE EXAMINATION, MARCH 2024

Course Code: 223AGE003

Course Name: DATA SCIENCE FOR ENGINEERS

Max. Marks: 60 Duration: 2.5 Hours

Answer any five full questions, each carries 12 marks.

1	a) It is observed that 50% of mails are spam. There is software that filters spam mail before reaching the inbox. It accuracy for detecting a spam mail is 99% and chances of tagging a non-spam mail as spam mail is 5%. If a certain mail is tagged as spam finds the probability that it is not a spam mail.	5
	b) Depict the relevance of measures of central tendency in data wrangling with a suitable example	7
2.	a) Calculate the inverse of the Matrix $\begin{matrix} 2 & 4 & -6 \\ 7 & 3 & 5 \\ 1 & -2 & 4 \end{matrix}$	4
	b)Find all Eigenvalues and Corresponding Eigenvectors for the matrix if $\begin{matrix} 2 & -3 & 0 \\ 2 & -5 & 0 \\ 0 & 0 & 3 \end{matrix}$	8
3.	a) A statistician wants to test the hypothesis H0: $\mu = 120$ using the alternative hypothesis Hα: $\mu > 120$ and assuming that $\alpha = 0.05$. For that, he took the sample values as $n = 40$, $\sigma = 32.17$ and $\bar{x} = 105.37$. Determine the conclusion for this hypothesis?	5
	b) Hypothesis testing is an integral part of statistical inference, list out the various types of hypothesis testing and also mentions their significances in data science.	7
4.	a) Brief in detail directional and non-directional hypothesis	6
	b) Differentiate null and alternate hypothesis and also elaborate on type 1 and type 2 errors	6
5.	a) Explain the concepts of Tuple, List and Directory in python with example	6
	b) Elucidate reinforcement learning and application in real world.	6

6. a) What is Feature Engineering , demonstrate with an example 6

b) Describe in detail different steps involved in data preprocessing. 6

7. a) Illustrate supervised learning model with linear regression model 5

b) Predict the probability for the given feature vector if an accident will happen or not? 7

Weather condition: rain, Road condition: good, Traffic condition: normal, Engine problem: no, the task is to predict using Naïve Bayes classification.

SNo.	Weather condition	Road condition	Traffic condition	Engine problem	Accident
1	Rain	bad	high	no	yes
2	snow	average	normal	yes	yes
3	clear	bad	light	no	no
4	clear	good	light	yes	yes
5	snow	good	normal	no	no
6	rain	average	light	no	no
7	rain	good	normal	no	no
8	snow	bad	high	no	yes
9	clear	good	high	yes	no
10	clear	bad	high	yes	yes

223AGE004	DESIGN THINKING	CATEGORY	L	T	P	CREDIT
		AUDIT COURSE	3	0	0	-

Preamble:

This course offers an introductory exploration of fundamental engineering concepts and techniques, the design process, analytical thinking and creativity, as well as the fundamentals and development of engineering drawings, along with their application in engineering problems.

Course Outcomes:

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

CO 1	Identify and frame design challenges effectively.
CO 2	Generate creative ideas through brainstorming and ideation
CO 3	Iterate on designs based on user insights
CO 4	Apply Design Thinking to real-world problems and projects.

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

AUDIT COURSES

Continuous Internal Evaluation Pattern: 40 marks

Course based task : 15 marks
Seminar/Quiz : 15 marks
Test paper, 1 no. : 10 marks
Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: 60 marks

The examination will be conducted by the respective College. The examination willbe for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 marks.

Model Question paper

		SET1	**Total Pages:**
Reg No.:_________________		Name:_____________________________	

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
THIRD SEMESTER M.TECH DEGREE EXAMINATION, MARCH 2024

Course Code: 223AGE004

Course Name: DESIGN THINKING

Max. Marks: 60 | Duration: 2.5 Hours

Answer any five full questions, each carries 12 marks.

1 a)	How can a multidisciplinary team collaborate effectively to implement design principles?	7
1 b)	What are the key differences between human-centred design and other design methodologies?	5
2 a)	How do you measure the success of a design project in terms of user satisfaction and impact?	7
2 b)	How does the iterative nature of the design process contribute to better outcomes	5

3 a)	What are the fundamental principles of effective brainstorming, and how do they differ from traditional problem-solving approaches?	7
3 b)	What are some key principles of ergonomic design, and how do they contribute to the usability and comfort of products?	5
4 a)	Enumerate some examples of successful and unsuccessful market testing scenarios, and what lessons can be learned from these experiences to improve future product or service launches?	7
4b)	What is the primary purpose of creating prototypes in the design and development process?	5
5	What strategies and methodologies can designers use to embrace agility and respond quickly to changing user needs and market dynamics?	12
6	Illustrate any four examples of successful bio-mimicry applications in various industries.	12
7	What ethical considerations should designers keep in mind when designing for diverse user groups?	12
	****	

Syllabus:

Module 1

Design process: Traditional design, Design Thinking Approach, Introduction to Design Thinking, History and evolution of Design Thinking, Role of design thinking in the human-centred design process. Design space, Design Thinking in a Team Environment, Team formation.

Module 2

Design Thinking Stages: Empathize, Define, Ideate, Prototype and Test. The importance of empathy, Building a user-centred mindset. Problem statement formulation, User needs and pain points, establishing target specifications, Setting the final specifications.

Module 3

Generating Ideas, Brainstorming techniques, Application of Aesthetics and Ergonomics in Design. Bio-mimicry, Conceptualization, Visual thinking, Drawing/Sketching, Presenting ideas.

Module 4

Use of prototyping, Types of prototypes, Rapid prototyping techniques, User testing and feedback collection, Iterative prototyping, testing to gauge risk and market interest

Module 5

Entrepreneurship/business ideas, Patents and Intellectual Property, Agility in design, Ethical considerations in design. Overcoming common implementation challenges

Corse Plan SyllabusandCorsePlan (For 3credit courses, thec ontent can be for 40 hrs and for2credit courses, the content can be for 26 hrs. The audit course in third semester can have content for 30hours).

No	Topic	No. of lectures
1	**Design process:**	
1.1	Design process: Traditional design, Design Thinking Approach, Introduction to Design Thinking, History and evolution of Design Thinking.	3
1.2	Role of design thinking in the human-centred design process. Design space,	2
1.3	Design Thinking in a Team Environment, Team formation.	2

2	**Design Thinking Stages:**	
2.1	Design Thinking Stages: Empathize, Define, Ideate, Prototype and Test.	2
2.2	The importance of empathy, Building a user-centred mindset.	2
2.3	Problem statement formulation, User needs and pain points, establishing target specifications, Setting the final specifications.	3
3	**Ideation**	
3.1	Generating Ideas, Brainstorming techniques.	2
3.2	Application of Aesthetics and Ergonomics in Design. Bio-mimicry.	3
3.3	Conceptualization, Visual thinking, Drawing/Sketching, Presenting ideas.	2
4	**Prototyping and testing**	
4.1	Use of prototyping, Types of prototypes, Rapid prototyping techniques.	3
4.2	User testing and feedback collection, Iterative prototyping, testing to gauge risk and market interest	2
5	**IPR in design**	
5.1	Entrepreneurship/business ideas, Patents and Intellectual Property.	2
5.2	Agility in design, Ethical considerations in design. Overcoming common implementation challenges	2

Reference Books

1. Christoph Meinel, Larry Leifer and Hasso Plattner- "Design Thinking: Understand – Improve – Apply", Springer Berlin, Heidelberg, 2011.
2. Thomas Lockwood and Edgar Papke – "Design Thinking: Integrating Innovation, Customer Experience, and Brand Value", Allworth Press, 2009.
3. Pavan Soni – "Design Your Thinking", Penguin Random House India Private Limited, 2020.
4. Andrew Pressman- "Design Thinking : A Guide to Creative Problem Solving for Everyone", Taylor & Francis, 2018.
5. N Siva Prasad, "Design Thinking Techniques an Approaches" Ane Books Pvt. Ltd.,2023

SYLLABUS

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
223AGE005	FUNCTIONAL PROGRAMMING IN HASKELL	AUDIT COURSE	3	0	0	-

Preamble: This course introduces a functional programming approach in problem solving. Salient features of functional programming like recursion, pattern matching, higher order functions etc. and the implementation in Haskell are discussed.

Course Outcomes:

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

CO 1	Understand the functional programming paradigm which is based on the mathematics of lambda calculus.
CO 2	Develop Haskell programs using functions, guards and recursive functions
CO 3	Apply the concept of tuples, lists and strings in Haskell programming
CO 4	Apply the concept of algebraic data types, abstract data types, modules, recursive data types and user defined data types in Haskell programming
CO 5	Develop Haskell programs with files for reading input and storing output

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation: 40 marks

Course based task : 15 marks

Seminar/Quiz : 15 marks

Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus**.**

End Semester Examination: 60 marks

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 marks.

Model Question paper

		Total Pages:
Reg No.:________________		Name:___________________________
APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY THIRD SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2023		
Course Code: 223AGE005		
Course Name: Functional Programming in Haskell		
Max. Marks: 60		Duration: 2.5 Hours
Answer any five full questions, each carries 12 marks.		

1 a.	Explain the basic differences between imperative style programming and functional style programming.	3
1 b.	Analyse each of the following lambda expressions to clarify its structure. If the expression is a function, identify the bound variable and the body expression, and then analyse the body expression. If the expression is an application, identify the function and argument expressions, and then analyse the function and argument expressions: i) λa.(a λb.(b a)) ii) λx.λy.λz.((z x) (z y)) iii) (λf.λg.(λh.(g h) f) λp.λq.p)	9
2 a.	Design a recursive function to find 2^n where n is a natural number.	4

2 b.	Explain various forms of function definitions in Haskell with the help of examples.	8
3 a.	Explain any three list operations along with function definitions and examples.	6
3 b.	Write a program to duplicate only even numbers among the elements of a list using a Haskell function by (i) Recursion (ii) List Comprehension and explain. Example : λ> dupli [1, 2, 3] ANS: [2,2]	6
4	Write Recursive definitions along with an explanation for the below arithmetic operations. Illustrate the recursive flow with the help of a diagram. i. add x y ii. mult x y iii. div x y	12
5	Write the Haskell code to split a list into two lists such that the elements with odd index are in one list while the elements with even index are in the other list.	12
6 a	Give the type definition of a binary tree along with explanation of two functions on binary trees.	6
6 b	Define a queue data type in Haskell along with any two operations on it with examples.	6
7 a.	Explain the basic steps of reading from files and writing to files in Haskell.	4
7 b.	Write a Haskell program to read from the file "input.txt", display the contents on the screen and write the contents to another file "output.txt".	8
	****	

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

Module 1 (5 Hrs)

Introduction to Functional Programming: Programming language paradigms, imperative style programming, comparison of programming paradigms.
Functional programming, Functions - Mathematical concepts and terminology, Lambda calculus, Function definitions, programs as functions, Functional programming Languages. Haskell basics, GHCi interpreter.

Module 2 (6 Hrs)

Programming in Haskell: Expressions and evaluation, Lazy evaluation, let expressions, scopes.

Basic data types in Haskell, operators, infix operators, associativity and precedence, Arithmetic functions.

types, definitions, currying and uncurrying, type abstraction.

Function definitions, pattern matching, guards, anonymous functions, higher order functions.

Recursion, Programming exercises.

Module 3 (7 Hrs)

Data types: tuples and lists: Tuples , Lists: building lists, decomposing lists, functions on lists, built-in functions on lists, primitive and general recursion over lists, infinite lists.

Strings: functions on strings.

Polymorphism and overloading, conditional polymorphism

Module 4 (6 Hrs)

Type classes, Algebraic data types, Modules, Recursive data types.

User defined data types, Records, Stacks, Queues, Binary trees, Constructors, Destructors.

Module 5 (6 Hrs)

Functor, Applicative functor, Monad

Programming with actions: Functions vs actions, Basics of input / output, the do notation, interacting with the command line and lazy I/O, File I/O.

No	Topic	No. of Lectures
1	**Introduction to Functional Programming**	
1.1	Programming language paradigms, imperative style programming, comparison of programming paradigms	1
1.2	Functional programming, Functions - Mathematical concepts and terminology	1
1.3	Lambda calculus	1
1.4	Function definitions, programs as functions, Functional programming Languages	1
1.5	Haskell basics, GHCi interpreter	1
2	**Haskell basics**	
2.1	Expressions and evaluation, Lazy evaluation	1
2.2	let expressions, scopes, Basic data types in Haskell	1
2.3	operators, infix operators, associativity and precedence, Arithmetic	1

	functions	
2.4	types, definitions, currying and uncurrying, type abstraction.	1
2.5	Function definitions, pattern matching, Guards	1
2.6	anonymous functions, higher order functions, Recursion	1
3	**Data types: tuples and lists**	
3.1	Tuples , Lists: building lists, decomposing lists	1
3.2	functions on lists, built-in functions on lists	1
3.3	primitive and general recursion over lists	1
3.4	infinite lists	1
3.5	Strings: functions on strings	1
3.6	Polymorphism and overloading	1
3.7	conditional polymorphism	1
4	**User defined data types**	
4.1	Type classes, Algebraic data types, Modules	1
4.2	Recursive data types	1
4.3	User defined data types, Records	1
4.4	Stacks, Queues	1
4.5	Binary trees	1
4.6	Constructors, Destructors	1
5	**Programming with actions**	
5.1	Functor, Applicative functor,	1
5.2	Monad	1
5.3	Programming with actions: Functions vs actions, Basics of input / output, the do notation	1
5.4	interacting with the command line and lazy I/O	1
5.5	File I/O	2

Reference Books

[1] Richard Bird, “Introduction to functional programming using Haskell', second edition, Prentice hall series in computer science

[2] Bryan O'Sullivan, Don Stewart, and John Goerzen, “Real World Haskell”

[3] Richard Bird, "Thinking Functionally with Haskell", Cambridge University Press, 2014

[4] Simon Thompson, "Haskell: The Craft of Functional Programming", Addison-Wesley, 3rd Edition, 2011

[5] H. Conrad Cunningham, "Notes on Functional Programming with Haskell", 2014

[6] Graham Hutton, "Programming in Haskell", Cambridge University Press, 2nd Edition, 2016

[7] Alejandro Serrano Mena, "Practical Haskell: A Real-World Guide to Functional Programming", 3rd Edition, Apress, 2022

[8] Miran Lipovaca, "Learn You a Haskell for Great Good!: A Beginner's Guide", No Starch Press, 2011

223AGE010	REUSE AND RECYCLE TECHNOLOGY	CATEGORY	L	T	P	CREDIT
		AUDIT COURSE	3	0	0	-

Preamble: "Reuse and Recycle Technology" typically focuses on sustainable practices and technologies aimed at reducing waste, conserving resources, and promoting environmental responsibility.

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

CO 1	Explain the principles and technologies behind waste reduction, resource conservation, and sustainable practices
CO 2	Describe and Analyze waste generation and management.
CO 3	Apply the knowledge of various reuse strategies and their application in different industries and Analyze various recycling technologies
CO 4	Appraise the methods of E-waste management and Eco friendly packaging
CO 5	Comprehend Environmental Regulations and Policies**,** Understand the importance of environmental regulations and policies in addressing environmental challenges

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	**End Semester Examination**
Understand	60%
Apply	20%
Analyse	20%

Mark distribution

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

Continuous Internal Evaluation Pattern: 40 marks

Course based task : 15 marks
Seminar/Quiz : 15 marks
Test paper, 1 no. : 10 marks
Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: 60 marks

The examination will be conducted by the respective College. The examination willbe for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 marks.

Model Question paper

AUDIT COURSE

223AGE010 - REUSE AND RECYCLE TECHNOLOGY

Answer any five full questions, each carries 12 marks.

1.	(a) What are the 3 pillars of sustainability? *(b)* What is sustainable waste management? What makes sustainable waste management so important?	5 7
2.	(a)How do the three categories of municipal solid waste differ? *(b)* Discuss the municipal waste collection and management?	5 7
3.	(a)Explain the major differences between Reuse and Recycle? *(b)* Give an overview of recycling technologies used for any two materials. Discuss the Process involved.	5 7
4.	(a)What are the common source of E-waste *(b)* What are the challenges and opportunities in E-waste management	5 7
5.	(a)What is the case law for waste recycling in India *(b)* Discuss sustainable packaging and its environmental impacts	5 7
6.	Explain the various environmental regulations in India for addressing Environmental challenges	12
7.	a) Give examples of water reuse technologies in circular economy b) How can we reduce e-waste with sustainable solutions	5 7

Syllabus

Module	Content	Hours	Semester Exam Marks (%)
I	**Introduction to Sustainability**, Understanding sustainability and its importance, The three pillars of sustainability: Environmental, Social, and Economic. Biodiversity conservation, Climate change and mitigation Sustainable resource management.	**6**	**20**
II	**Waste Management,** Definition and classification of waste, Waste Generation and Composition**,** Waste Collection and Transportation, Waste Segregation and Sorting. Waste Disposal Methods Historical perspectives on waste management, The three Rs: Reduce, Reuse, and Recycle.	**6**	**20**
III	**Recycling and Reuse:** Importance of reuse, Application of reuse in various industries, Challenges and opportunities in reuse, Overview of recycling technologies, Circular economy, Sorting and processing of recyclable materials, Advanced recycling methods. Emerging technologies in recycling.	**6**	**20**
IV	**E-waste Recycling,** Challenges and environmental impact of electronic waste, E-waste recycling methods and regulations, Sustainable electronics design, **Sustainable Packaging,** Packaging materials and their environmental impact, Eco-friendly packaging alternatives, Packaging design for sustainability	**6**	**20**
V	**Environmental Regulations and Policies,** Understand the importance of environmental regulations and policies in addressing environmental challenges, National and international waste and recycling regulations, Compliance and enforcement, Industry standards and certifications	**6**	**20**

Course Plan

No	Topic	No. of Lectures
1	**Introduction to Sustainability (6)**	
1.1	Understanding sustainability and its importance	1
1.2	The three pillars of sustainability: Environmental, Social, and Economic.	3
1.3	Biodiversity conservation, Climate change and mitigation	1
1.4	Sustainable resource management	1
2	**Waste Management (6)**	
2.1	Definition and classification of waste	1
2.2	Waste Generation and Composition	1
2.3	Waste Collection and Transportation.	1
2.4	Waste Segregation and Sorting.	1
2.5	Waste Disposal Methods	1
2.6	Historical perspectives on waste management, The three Rs: Reduce, Reuse, and Recycle.	1
3	**Recycling and Reuse (6)**	
3.1	Importance of reuse, Examples of reuse in various industries.	1
3.2	Challenges and opportunities in reuse	1
3.3	Overview of recycling technologies, Sorting and processing of recyclable materials	2
3.4	Advanced recycling methods	1
3.5	Emerging technologies in recycling.	1
4	**E-waste Recycling (6)**	
4.1	Challenges and environmental impact of electronic waste	1
4.2	E-waste recycling methods and regulations	1
4.3	Sustainable electronics design	1
4.4	Packaging materials and their environmental impact	1
4.5	Eco-friendly packaging alternatives	1
4.6	Packaging design for sustainability	1
5	**Environmental Regulations and Policies (6)**	
5.1	Importance of environmental regulations and policies in addressing environmental challenges	2
5.2	National and international waste and recycling regulations	2
5.3	Industry standards and certifications, Compliance and enforcement	2

Reference Books

1. Sustainable Engineering: Concepts, Design and Case Studies, David T. Allen, Pearson Publication.
2. A Comprehensive Book on Solid Waste Management with Application, Dr. H.S. Bhatia , Misha Books, 2019
3. "Cradle to Cradle: Remaking the Way We Make Things" by William McDonough and Michael Braungart.
4. "Recycling of Plastic Materials" edited by Vijay Kumar Thakur
5. E-waste: Implications, Regulations and Management in India and Current Global Best Practices, Rakesh Johri, TERI
6. "Sustainable Packaging", Subramanian Senthilkannan Muthu , Springer Nature.
7. **I**ndian Environmental Law: Key Concepts and Principles " Orient Black swan Private Limited, New Delhi.

223AGE012	EXPERT SYSTEMS	CATEGORY	L	T	P	CREDIT
		AUDIT COURSE	3	0	0	-

Preamble: The course aims to provide an understanding of the basic concepts of Artificial Intelligence (AI) and Expert Systems. The course also covers the knowledge representation in expert systems, classes of expert systems, applications of expert systems.

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

CO 1	Explain the concepts of Artificial Intelligence and different ways of knowledge representations.
CO 2	Explain the components of expert systems, development stages of expert systems and tools available for expert system design.
CO 3	Apply the concept of knowledge representation in expert systems
CO 4	Differentiate the classes of expert systems and examine properties of existing systems

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO7
CO 1	1		2	1	2	2	
CO 2	1		1	3	2	2	
CO 3	1		1	2	2	2	
CO 4	2		2	2	3	2	

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Course based task (Project/Assignments/Simulations/Case studies): 15 marks

Seminar/Quiz : 15 marks

Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:**60 marks**

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 mark.

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY THIRD SEMESTER M.TECH DEGREE EXAMINATION, MARCH 2024		
Course Code: 223AGE012		
Course Name: EXPERT SYSTEMS		
Max. Marks: 60		Duration: 2.5 Hours
Answer any five full questions, each carries 12 marks.		
1	a) What are the types of AI? Explain with examples .	6
	b) What do you mean by knowledge in AI and explain the different ways of knowledge representation used in AI?	6
2.	a) Write note on semantic network.	6
	b) What are Predicates? Explain its syntax and semantics.	6
3.	a) Write notes on different tools available for expert system design.	6
	b). What are the different stages in the development of an expert system?	6
4.	a) Illustrate Conceptual Dependencies with an example.	6
	b) Illustrate with an example the Structured Knowledge representation of an Expert System.	6
5.	a) What do you mean by Frame based Expert System? Explain	6
	b)Explain the architecture of MYCIN	6
6.	a)Explain Fuzzy based expert systems	6
	b) Explain the neural network based expert systems	6
7.	a) Explain any two applications of expert systems?	6
	b)What are the limitations of expert system ? Explain	6

Syllabus

Module	Content	Hours	Semester Exam Marks (%)
I	Overview of Artificial Intelligence (AI): Definition & Importance of AI. Knowledge general concepts: Definition and Importance of knowledge, Knowledge-Based Systems, Knowledge organization, Knowledge Manipulation and acquisition. Knowledge Representation: Introduction, Syntax and Semantics- Propositional logic and predicate logic.	**6**	**20**
II	Basic concepts of expert systems-Introduction to expert systems, Components of expert systems. Features of Expert System, Stages in the development of expert system, Types of tools available for expert system design	**6**	**20**
III	Knowledge representation in expert systems: Structured Knowledge representation: Graphs, Frames and related structures, Associative networks, Conceptual dependencies, Examples of structured knowledge representation.	**6**	**20**
IV	Classes of expert systems: Rule-based expert systems, Example- MYCIN, Frame-based expert system, terminologies, IF-THEN structure. Fuzzy and Neural network based expert systems(basic concepts)	**7**	**20**
V	Currents trends in expert systems, Advantages and limitations of expert systems, Applications of expert systems.	**5**	**20**

Course Plan

No	Topics	No. of Lectures
1	**Overview of Artificial Intelligence& Knowledge general concepts**	
1.1	Definition & Importance of AI	1
1.2	Definition and Importance of Knowledge,	1
1.3	Knowledge-Based Systems, Knowledge Organization	1
1.4	Knowledge Manipulation and acquisition	1
1.5	Knowledge Representation: Introduction, Syntax and Semantics	1
1.6	Propositional logic and predicate logic	1
2	**Basic concepts of expert systems**	
2.1	Introduction to Expert System, Components of expert systems	2
2.2	Features of Expert System, Stages in the development of expert system	2
2.3	Types of tools available for expert system design	2
3	**Knowledge representation in expert systems**	
3.1	Structured Knowledge representation	1
3.2	Graphs, Frames and Related Structures	2
3.3	Associative Networks, Conceptual Dependencies	2
3.4	Examples of structured knowledge representation	1
4	**Classes of expert systems**	
4.1	A rule-based expert system -Introduction	1
4.2	MYCIN	1
4.3	IF-THEN structure	1
4.4	Frame-based expert system	2
4.5	Fuzzy based expert systems	1
4.6	Neural network based expert systems	1
5	**Currents trends and applications of expert systems**	
5.1	Currents trends of expert systems	2
5.2	Advantages and limitations of expert systems	1
5.3	Applications of expert systems	2

Reference Books

1. E. Rich & K. Knight - Artificial Intelligence, 2/e, TMH, New Delhi, 2005.
2. P.H. Winston - Artificial Intelligence, 3/e, Pearson Edition, New Delhi, 2006.
3. D.W. Rolston - Principles of AI & Expert System Development, TMH, New Delhi
4. Kevin Night and Elaine Rich, Nair B., “Artificial Intelligence (SIE) “, McGraw Hill – 2010
5. Dan W Patterson, ‘Introduction to Artificial intelligence and Expert systems’, Prentice Hall of India Pvt. Ltd,2007
6. Russel (Stuart), ‘Artificial Intelligence- Modern approach, Pearson Education series in AI’, 3rd Edition, 2009.
7. I. Gupta, G. Nagpal · Artificial Intelligence and Expert Systems, Mercury Learning and Information -2020

223AGE011	SYSTEM MODELLING	CATEGORY	L	T	P	CREDIT
		AUDIT COURSE	3	0	0	-

Preamble: Study of this course provides the learners a clear understanding of fundamental concepts in simulation and modelling. This course covers the different statistical models, importance of data collection and various types of simulations. The course helps the learners to find varied applications in engineering, medicine and bio-technology.

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

CO 1	Analyse the requirement and find appropriate tool for simulation.
CO 2	Differentiate the different statistical models.
CO 3	Discuss the different techniques for generating random numbers.
CO 4	Analyse the different methods for selecting the different input models..
CO 5	Discuss the different measures of performance and their estimation

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Course based task (Project/Assignments/Simulations/Case studies): 15 marks
Seminar/Quiz: 15 marks
Test paper, 1 no.: 10 marks
Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 marks.

Model Question paper

AUDIT COURSE

223AGE001 – SYSTEM MODELLING

Answer any five questions Each carries 12 marks

PART A

1. a. Discuss the advantages and disadvantages of simulation. (5marks)

   b. What are the areas of applications of simulation (7 marks)

2. a.A bus arrives every 20 minutes at a specified stop beginning at 6:40 A.M. and continuing until 8:40 A.M. A certain passenger does not know the schedule, but arrives randomly (uniformly distributed) between 7:00A.M. and 7:30 A.M. every morning. What is the probability that the passenger waits more than 5 minutes for a bus? (5 marks)

   b. A production process manufactures computer chips on the average at 2% nonconforming. Every day, a random sample of size 50 is taken from the process. If the sample contains more than two nonconforming chips, the process will be stopped. Compute the probability that the process is stopped by the sampling scheme. (7 marks)

3. a.Discuss the different types of tests for random numbers. (5 marks)

   b. Generate random numbers using multiplicative congruential method with X0 = 5, a 11, and m = 64. (7 marks)

4. a. What are the different methods of data collection. (4marks)

   b. Records pertaining to the monthly number of job-related injuries at an underground coalrnine were being studied by a federal agency. The values for the past 100 months were as follows:

Injuries per Month	Frequency of Occurrence
0	35
1	40
2	13
3	6
4	4
5	1
6	1

(a) Apply the chi-square test to these data to test the hypothesis that the underlying distribution is Poisson. Use the level of significance α== 0.05.

(b) Apply the chi-square test to these data to test the hypothesis that the distribution is Poisson with mean 1.0. Again let α = 0.05. ·

c) What are the differences between parts (a) and (b), and when might each case arise? (8 marks)

5. a.What is the difference between validation and verification.(5 marks)
   b. Discuss the different measures of performance and their estimation(7 marks)
6. a. Discuss the different methods of parameter estimation(5 marks)
   b. With an example, describe the Poisson process.(7 marks)
7. a. Distinguish between discrete and continuous systems(5 marks)
   b.What are the different components of a simulation system(7 marks)

Syllabus

Module	**Content**	**Hours**	**Semester Exam Marks (%)**
I	When simulation is the appropriate tool. Advantages and disadvantages of Simulation; Areas of application, Systems and system environment; Components of a system; Discrete and continuous systems, Model of a system; Types of Models, Discrete-Event System Simulation, Steps of a simulation study.	**6**	**20**
II	Review of terminology and concepts, Useful statistical models, Discrete distributions. Continuous distributions, Poisson process, Empirical distributions. (basic idea only)	**6**	**20**
III	Properties of random numbers; Generation of pseudo-random numbers, Techniques for generating random numbers, Tests for Random Numbers	**6**	**20**
IV	Data Collection; Identifying the distribution with data, Parameter estimation, Goodness of Fit Tests, Fitting a non-stationary Poisson process, Selecting input models without data, Multivariate and Time-Series input models.	**6**	**20**
V	Measures of performance and their estimation, Output analysis for terminating simulations, Output analysis for steady-state simulations, Verification, calibration and validation	**6**	**20**

Course Plan

No	Topic	No. of Lectures
1	**Introduction**	
1.1	When simulation is the appropriate tool	1
1.2	Advantages and disadvantages of Simulation;	1
1.3	Areas of application, Systems and system environment;	1
1.4	Components of a system; Discrete and continuous systems,	1
1.5	Model of a system; Types of Models,	1
1.6	Discrete-Event System Simulation ,Steps of a simulation study	1
2	**Statistical Models in Simulation**	
2.1	Review of terminology and concepts, Empirical distributions. (basic idea only)	1
2.2	Useful statistical models,	1
2.3	Discrete distributions.	1
2.4	Continuous distributions,.	1
2.5	Poisson process	1
2.6	Empirical distributions	1
3	**Random Number Generation**	
3.1	Properties of random numbers;	1
3.2	Generation of pseudo-random numbers,	
3.3	Techniques for generating random numbers	1
3.4	Techniques for generating random numbers(cont)	1
3.5	Tests for Random Numbers	1
3.6	Tests for Random Numbers(cont)	1
4	**Input Modelling**	
4.1	Data Collection;	1
4.2	Identifying the distribution with data.	1
4.3	Parameter estimation, Goodness of Fit Tests	1
4.4	Fitting a non-stationary Poisson process	1
4.5	Selecting input models without data,	1
4.6	Multivariate and Time-Series input models	1
5	**Measures of Performance and their Estimation**	
5.1	Measures of performance and their estimation	1
5.2	Measures of performance and their estimation(cont)	1
5.3	Output analysis for terminating simulations	1
5.4	Output analysis for steady-state simulations	1
5.5	Verification, calibration and validation	1
5.6	Verification, calibration and validation(cont)	1

Textbooks:

1. Jerry Banks, John S. Carson II, Barry L. Nelson, David M. Nicol: Discrete-Event System Simulation, 5th Edition, Pearson Education, 2010.

Reference Books:

1. Lawrence M. Leemis, Stephen K. Park: Discrete – Event Simulation: A First Course, Pearson Education, 2006.

2. Averill M. Law: Simulation Modeling and Analysis, 4 th Edition, Tata McGraw-Hill, 2007

3. System Modelling and Response by Ernest O. Doebelin

4. Averill M Law, “Simulation Modeling and Analysis”,McGraw-Hill Inc,2007 Geoffrey Gorden, “System Simulation”,Prentice Hall of India,1992.

223AGE009	Principles of Automation	CATEGORY	L	T	P	CREDIT
		CREDIT COURSE	3	0	0	0

Preamble:

This course deals in detail with the various aspects of automation such as sensors, actuators, controllers, mechanical and electrical elements and their integration for automating new and existing manufacturing and process industries and applications. This course will be beneficial to students in designing automation schemes for industries and to design automated systems

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

CO 1	Explain the fundamentals of sensor systems and to choose a suitable sensor system for the given application based on the evaluation of the constraints.
CO 2	Explain the fundamentals of signal conditions and to design a suitable signal conditioning scheme for given application.
CO 3	Describe the characteristics of various actuator systems and to decide the right type of actuator for the given application.
CO 4	Describe the importance of an industrial robot and fundamentals of numerical control in automation.
CO 5	Explain the fundamentals of controllers used in industrial automation and to construct simple automation schemes by ladder logic programs.

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

Assessment Pattern

Bloom's Category	**End Semester Examination**
Understand	70 %
Apply	30 %

Mark distribution

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

Continuous Internal Evaluation Pattern: 40 marks
Course based task (Project/Assignments/Simulations/Case studies): 15 marks
Seminar/Quiz: 15 marks
Test paper, 1 no.: 10 marks
Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:**60 marks**
The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 marks.

Model Question Paper
223AGE009 Principles of Automation

Time 2.5 Hrs | Marks 60

Answer any five questions Each carries 12 marks

1. (a) Differentiate the static and dynamic characteristics of a temperature sensor and explain how it affects the selection of a suitable temperature sensor. (6 marks)
   (b) Explain the working of a strain-gauge. (6marks)

2. (a) Explain why anti-aliasing filters are used in analog to digital converters. (3 marks)
   (b) Design a first order low pass filter with a cutoff frequency of 2 kHz. (9 marks)

3. (a) What are the factors to consider while deciding choosing between hydraulic, pneumatic or electrical actuation systems for an automation scheme? (4 marks)
   (b) Explain the working of a three-way pressure reducing valve. (4 marks)
   (c) Explain the working of solenoids. In what applications would you use a Solenoid valve. (4 marks)

4. (a) Explain the principle of the Touch sensor and also mention how they are used in robots. (5 marks)
   (b) Explain the basic terminologies in robotic system and also explain the components of robotic system. (7 marks)

5. (a)With neat schematic explain the architecture of the PLC. (6 marks)
   (b) Explain the use of an up-down counter in PLC with a suitable example. (6 marks)

6. (a) Write short note on SCADA. What is difference PLC and SCADA? (3 marks)

   (b)Construct a ladder logic for controlling a process tank as per the logic given below;
      i.The tank should be filled by a valve V1 when low level float switch L1 is ON and an external input S1 is received.

ii.V1 should be closed when the liquid level reaches a high-level float switch L2.
iii. An agitator motor should be turned on after a delay of 5sec after L2 is triggered.
iv. After agitating for 30mins, contents of the tank should be emptied by opening another valve V2.
v. The temperature should be maintained at 70℃ using a thermostat T1 and Heater H (9 marks)

7. (a) Explain the levels of Automation. (6 marks)
(b) Explain the working of Flow sensor (6 marks)

Syllabus and Course Plan

No	Topics	No. of Lectures
1	**Introduction to Industrial Automation**	
1.1	Basic Elements of an Automated System, Levels of Automation	2
1.2	Hardware components for Automation: Sensors, classification, Static and dynamic behaviour of sensors.	2
1.3	Basic working principle of different sensors: Proximity sensors, Temperature sensors, flow sensors, Pressure sensors, Force sensors. Position sensors	4
2	**Signal conditioning**	
2.1	Need for signal conditioning, Types of signal conditioning.	2
2.2	Signal conditioning using operational amplifier-Amplifier (Inverting and Non-inverting) and Filter circuits (Basic concepts). Design of first order low pass filter.	2
2.3	Signal conditioning for data acquisition systems, anti-aliasing filters, Analog–Digital Conversions, Analog-to-Digital Converters (ADC)- Steps in analog-to-digital conversion, Successive Approximation Method, Digital-to-Analog Converters (DAC)- Steps in digital to analog conversion, Zero-order and first order data hold circuits	4
3	**Actuators**	
3.1	Types of actuators- mechanical, electrical, pneumatic and hydraulic actuators. (Basic working principle)	2
3.2	Mechanical systems for motion conversion, transmission systems	3
3.3	Solenoids, Electric and stepper motors control.	3
4	**Robotics and Automated Manufacturing Systems**	
4.1	Robot Anatomy and Related Attributes: Joints and Links, Common Robot Configurations, Joint Drive Systems, Sensors in Robotics (Basic concepts)	3
4.2	Robot Control Systems, Applications of Industrial Robots- Material handling	4
4.3	Fundamentals of Numerical control (NC) Technology	1
5	**Discrete Control and Programmable Logic Controllers**	

5.1	Discrete Process Control: Logic and Sequence control	2
5.2	Ladder Logic Diagrams, Programmable Logic Controllers: Components of the PLC, PLC Operating Cycle, Programming the PLC (Basic concepts only)	4
5.3	Introduction to Distributed control system (DCS) and Supervisory Control and Data Acquisition Systems (SCADA)	2

Reference Books

1. Mikell Groover, Automation, Production Systems, and Computer-Integrated Manufacturing, 5th Edition, Pearson, 2019.
2. Yoram Koren, "Computer Control of Manufacturing Systems",TataMcGraw Hill Edition2005.
3. S. R. Deb; Sankha Deb. Robotics Technology and Flexible Automation, Second Edition McGraw-Hill Education: New York, 2010.
4. W. Bolton, "Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering" - PrenticeHall- 2013 - 5th Edition.
5. Doebelin, E.O. and Manic, D.N., "Measurement Systems: Applications and Design", 7th Edition, McGraw Hill, 2019.
6. Krishna Kant, Computer Based Industrial Control-, EEE-PHI,2nd edition,2010.
7. Nathan Ida, Sensors, Actuators, and Their Interfaces- A multidisciplinary introduction, 2nd Edition, IET Digital Library, 2020.
8. Salivahanan, S., and VS Kanchana Bhaaskaran. Linear integrated circuits. McGraw-Hill Education, 2nd edition, 2014.
9. Petruzella, Frank D. Programmable logic controllers. Tata McGraw-Hill Education, 2005
10. Chapman and Hall, "Standard Handbook of Industrial Automation", Onsidine DM C & Onsidine GDC", NJ, 1986

223AGE002	FORENSIC ENGINEERING	CATEGORY	L	T	P	CREDIT
		Audit Course	3	0	0	-

Preamble: This course explores various aspects of Forensic Engineering and different methods ,tools and procedures used by Engineers to investigate and analyze . The students will learn to develop their awareness in Forensic Engineering .

Pre-requisite: Nil

Course Outcomes:

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

CO 1	Identify the fundamental aspects of forensic Engineering
CO 2	Apply forensic Engineering in Practical work flow and Investigation
CO 3	Apply methods and analysis in Forensic Investigation
CO 4	Develop practical strategies and standards of Investigation
CO 5	Create an awareness in criminal cases and create Engineering expertise in court room on forensic Engineering

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO7
CO 1	2	2	3	3	3	3	
CO 2	2	2	3	3	3	3	1
CO 3	3	3	3	3	3	3	1
CO 4	3	3	3	3	3	3	1
CO 5	3	3	3	3	3	3	

Assessment Pattern

Bloom's Category	Continuous Internal Evaluation	End Semester Examination
Apply	40 %	60 %
Analyse	40 %	40 %
Evaluate	20 %	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation: 40 marks

Course based task :15marks

Seminar/Quizz :15marks

Test paper :10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination: 60 marks

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 marks.

Model Question paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

THIRD SEMESTER M. TECH DEGREE EXAMINATION

Course Code: 223AG002

Course Name: FORENSIC ENGINEERING

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

PART A

Answer any 5 questions, each question carries 12 marks. **Marks**

1.	(a)	What are the uses of forensic engineering in legal laws ?	(7)
	(b)	Discuss the professional responsibility of a forensic Engineer .	(5)
2.	(a)	What are the steps in preliminary on site Investigation ?	(7)
	(b)	With suitable examples, explain photo cataloguing?	(5)
3.	(a)	Discuss STEP method .	(7)
	(b)	Explain root cause Analysis	(5)
4.	(a)	Detail about EDAX Method.	(7)
	(b)	Enlist the uses of NDT in forensic Analysis with example	(5)
5.	(a)	Differentiate NFPA & FMV Standards	(7)
	(b)	Briefly discuss the term Email Phishing ?	(5)
6.		Define the responsibility and duty of a forensic expert in the court.	(12)
7.		Explain Forensic Engineering workflow with examples	(12)

Syllabus and Course Plan

Module No	Topic	No. of Lectures (Hours)
1	**Module 01: Introduction to Forensic Engineering (6 Hours)**	
1.1	Forensic Engineering-Definition, Investigation Pyramid, Eyewitness Information, Role in Legal System	2
1.2	Scientific Method-Applying scientific methods in Forensic Engineering-Engineer as expert Witness-Scientific methods and legal system	2
1.3	Qualification of Forensic Engineer-Technical- Knowledge- Oral-written-Communication- other skills-Personality Characteristics	1
1.4	Ethics and professional responsibilities.	1
2	**Module 02: Forensic Engineering Workflow and Investigation Methods (6 Hours)**	
2.1	Forensic Engineering Workflow-Team &planning-preliminary onsite investigation. Sampling-selection of sample-collection- packing-sealing of samples.	2
2.2	Source and type of evidence - Paper documentation- digital documentation-electronic data. Physical Evidence-Collection of photograph-cataloguing -Recognizing the Evidence-organizing-Evidence Analysis -Reporting	2
2.3	Investigation Methods- Cause and Causal mechanism analysis-Time and event sequence-STEP method. Human Factors, Human errors - Analysis of Operative Instruction and working Procedures	2
3	**Module 03: Physical Product Failure & Analytical Methods (6 Hours)**	
3.1	Introduction to typical Forensic Engineering Tool box-NDT, Crack detection and human eye -Hardness testing- and Destructive testing Methods with case studies	2
3.2	Indirect stress strain Analysis-Brittle lacquer technique, Contact Radiography-Metallography-EDAX method	1
3.3	Forensic Optical Microscopy-Examination- Magnification-USB Microscopy -Wifi Enabled microscopy -Reflected microscopy	2
3.4	Novel Tools and System -Contour Method-Flash Thermography-Thermographic signal reconstruction (TSR)-Electromagnetically induced acoustic Emission (EMAE)-Pulsed Eddy Current (PEA)-Theory only	1
4	**Module 04: Cyber Forensic , Civil ,Electrical Accidents & Standards (6 Hours)**	
4.1	Basics of Digital & Cyber forensics: Technical concepts; labs and tools; collecting evidence Operating System Forensic basics with - Windows, Linux -Mobile Forensic-Anti forensics-Malware- Web attack forensics with Email Crimes-Cyber Laws	3
4.2	Different types of Forensic accident investigations- Civil Engineering-Structural- Road accidents -Fire accidents - Water related accidents-Electrical accidents and Investigation methods	2
4.3	Protocol for forensic Investigations-Standard guides-scope significance -use -procedures- reports. Standards – ASTM standards -FMV Standards -SAE Standards -Relevant Standards -NFPA Standards -International Standards	1

5	**Module 05: Engineer in the Court room& Criminal Cases (6 Hours)**	
5.1	Role of an Engineering Expert-Report-pre trial meetings-Alternative dispute resolution-Single joint expert. Engineer in the court room	2
5.2	Criminal Cases-Introduction-Counterfeit coins-fraudulent road accidents-Fraudulent Insurance claims.	2
5.3	Cyber Crimes and Cases- SIM Swapping -ATM Cloning-Microsoft Internal Spam- Intellectual property cases.	2

Reference Books

1. Colin R Gagg, *Forensic EngineeringThe Art &Craft of a failure detective* , Taylor & Francis Publishing, 2020
2. Luca Fiorentini ,Luca Marmo *Principles of Forensic Engineering Applied to Industrial Accidents* , Wiley, 2019
3. Harold Franck, Darren Franck , *Forensic Engineering Fundamentals* ,Taylor & Francis publishing 2013
4. Randall K Noon , *Forensic Engineering Investigation*, CRC press limited , 2001
5. Stephen E Petty , *Forensic Engineering: Damage assessment for residential and commercial structures* CRC press 2nd edition , 2017
6. Joshua B Kardon , *Guideliness for forensic Engineering practice* , ASCE, 2012
7. Richard W. Mclay and Robert N. Anderson, *Engineering standards for forensic Applications* , Academic Press; 1st edition 2018
8. Max M Houck ,*Forensic Engineering (Advanced forensic Science),* Academic press 1st edition 2017
9. Niranjan Reddy - Practical Cyber Forensics. *An Incident-based Approach to Forensic Investigations-Apress (2019)*
10. Peter Rhys Lewis, Ken Reynolds, Colin Gagg - *Forensic Materials Engineering Case Studies-CRC Press (2003) (1)*

INTERNSHIP

A student shall opt for carrying out the Internship at an Industry/Research Organization or at another institute of higher learning and repute (Academia). The organization for Internship shall be selected/decided by the students on their own with prior approval from the faculty advisor/respective PG Programme Coordinator/Guide/Supervisor. Every student shall be assigned an internship Supervisor/Guide at the beginning of the Internship. The training shall be related to their specialisation after the second semester for a minimum duration of six to eight weeks. On completion of the course, the student is expected to be able to develop skills in facing and solving the problems experiencing in the related field.

Objectives

- Exposure to the industrial environment, which cannot be simulated in the classroom and hence creating competent professionals for the industry.
- Provide possible opportunities to learn understand and sharpen the real time technical / managerial skills required at the job.
- Exposure to the current technological developments relevant to the subject area of training.
- Create conducive conditions with quest for knowledge and its applicability on the job.
- Understand the social, environmental, economic and administrative considerations that influence the working environment.
- Expose students to the engineer's responsibilities and ethics.

Benefits of Internship

Benefits to Students

- An opportunity to get hired by the Industry/ organization.
- Practical experience in an organizational setting & Industry environment.
- Excellent opportunity to see how the theoretical aspects learned in classes are integrated into the practical world. On-floor experience provides much more professional experience which is often worth more than classroom

teaching.

- Helps them decide if the industry and the profession is the best career option

  to pursue.
- Opportunity to learn new skills and supplement knowledge.
- Opportunity to practice communication and teamwork skills.
- Opportunity to learn strategies like time management, multi-tasking etc in an industrial setup.
- Makes a valuable addition to their resume.
- Enhances their candidacy for higher education/placement.
- Creating network and social circle and developing relationships with industry people.
- Provides opportunity to evaluate the organization before committing to a full time position.

Benefits to the Institute

- Build industry academia relations.
- Makes the placement process easier.
- Improve institutional credibility & branding.
- Helps in retention of the students.
- Curriculum revision can be made based on feedback from Industry/

  students.
- Improvement in teaching learning process.

Benefits to the Industry

- Availability of ready to contribute candidates for employment.
- Year round source of highly motivated pre-professionals.
- Students bring new perspectives to problem solving.
- Visibility of the organization is increased on campus.

- Quality candidate's availability for temporary or seasonal positions and projects.
- Freedom for industrial staff to pursue more creative projects.
- Availability of flexible, cost-effective workforce not requiring a long-term employer commitment.
- Proven, cost-effective way to recruit and evaluate potential employees.
- Enhancement of employer's image in the community by contributing to the educational enterprise.

Types of Internships

- Industry Internship with/without Stipend
- Govt / PSU Internship (BARC/Railway/ISRO etc)
- Internship with prominent education/research Institutes
- Internship with Incubation centres /Start-ups

Guidelines

- All the students need to go for internship for minimum duration of 6 to 8 weeks.
- Students can take mini projects, assignments, case studies by discussing it with concerned authority from industry and can work on it during internship.
- All students should compulsorily follow the rules and regulations as laid by industry.
- Every student should take prior permissions from concerned industrial authority if they want to use any drawings, photographs or any other document from industry.
- Student should follow all ethical practices and SOP of industry.
- Students have to take necessary health and safety precautions as laid by the industry.
- Student should contact his /her Guide/Supervisor from college on weekly basis to communicate the progress.
- Each student has to maintain a diary/log book
- After completion of internship, students are required to submit
    - Report of work done
    - Internship certificate copy
    - Feedback from employer / internship mentor
    - Stipend proof (in case of paid internship).

Total Marks 100: The marks awarded for the Internship will be on the basis of (i) Evaluation done by the Industry (ii) Students diary (iii) Internship Report and (iv) Comprehensive Viva Voce.

Continuous Internal Evaluation: 50 marks

Student's diary - 25 Marks

Evaluation done by the industry - 25 Marks

Student's Diary/ Daily Log: The main purpose of writing daily diary is to cultivatethe habit of documenting and to encourage the students to search for details. It develops the students' thought process and reasoning abilities. The students should record in the daily training diary the day to day account of the observations, impressions, information gathered and suggestions given, if any. It should contain the sketches & drawings related to the observations made by the students. The daily training diary should be signed after every day by the supervisor/ in charge of the section where the student has been working. The diary should also be shown to the Faculty Mentor visiting the industry from time to time and got ratified on the day of his visit. Student's diary will be evaluated on the basis of the following criteria:

- Regularity in maintenance of the diary
- Adequacy & quality of information recorded
- Drawings, design, sketches and data recorded
- Thought process and recording techniques used
- Organization of the information.

The format of student's diary

Name of the Organization/Section:

Name and Address of the Section Head:

Name and Address of the Supervisor:

Name and address of the student:

Internship Duration: From .... To ....

Brief description about the nature of internship:

Day	Brief write up about the Activities carried out: Such as design, sketches, result observed, issues identified, data recorded, etc.
1	
2	
3	

Signature of Industry Supervisor *Signature of Section Head/HR Manager*

Office Seal

Attendance Sheet

Name of the Organization/Section:

Name and Address of the Section Head:

Name and Address of the Supervisor:

Name and address of the student:

Internship Duration: From .... To ....

Month & Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	...
Month & Year																					
Month & Year																					

Signature of Industry Supervisor *Signature of Section Head/HR Manager*

Office Seal

Note:

- Student's Diary shall be submitted by the students along with attendance record and an evaluation sheet duly signed and stamped by the industry to the Institute immediately after the completion of the training.
- Attendance Sheet should remain affixed in daily training diary. Do not remove or tear it off.
- Student shall sign in the attendance column. Do not mark 'P'.
- Holidays should be marked in red ink in the attendance column. Absent should be marked as 'A' in red ink.

Evaluation done by the Industry (Marks 25)

Format for Supervisor Evaluation of Intern

Student Name :______________________________Date:___________________________

Supervisor Name :___________________________Designation:______________________

Company/Organization :____

Internship Address: ____

Dates of Internship: From_____________________To ___________________________

Please evaluate intern by indicating the frequency with which you observed the following parameters:

Parameters **Marks**	Needs improvement (0 – 0.25 mark)	Satisfactory (0.25 – 0.50 mark)	Good (0.75 mark)	Excellent (1 mark)
Behavior				
Performs in a dependable Manner				
Cooperates with coworkers and supervisor				
Shows interest in work				
Learns quickly				
Shows initiative				
Produces high quality work				
Accepts responsibility				
Accepts criticism				
Demonstrates organizational skills				
Uses technical knowledge and expertise				
Shows good judgment				
Demonstrates creativity/originality				
Analyzes problems effectively				
Is self-reliant				
Communicates well				
Writes effectively				
Has a professional attitude				
Gives a professional appearance				
Is punctual				
Uses time effectively				

Overall performance of student

Intern (Tick one) : Needs improvement (0 - 0.50 mark) / Satisfactory (0.50 – 1.0 mark) / Good (1.5 mark) / Excellent (2.0 mark)

Additional comments, if any (2 marks):

Signature of Industry Supervisor *Signature of Section Head/HR Manager*

Office Seal

End Semester Evaluation (External Evaluation): 50 Marks

Internship Report	-	25 Marks
Viva Voce	-	25 Marks

Internship Report: After completion of the internship, the student should prepare a comprehensive report to indicate what he has observed and learnt in the training period and should be submitted to the faculty Supervisor. The student may contact Industrial Supervisor/ Faculty Mentor for assigning special topics and problems and should prepare the final report on the assigned topics. Daily diary will also help to a great extent in writing the industrial report since much of the information has already been incorporated by the student into the daily diary. The training report should be signed by the Internship Supervisor, Programme Coordinator and Faculty Mentor.

The Internship report (25 Marks) will be evaluated on the basis of following criteria:

- Originality
- Adequacy and purposeful write-up
- Organization, format, drawings, sketches, style, language etc.
- Variety and relevance of learning experience
- Practical applications, relationships with basic theory and concepts taught in the course

Viva Voce (25 Marks) will be done by a committee comprising Faculty Supervisor, PG Programme Coordinator and an external expert (from Industry or research/academic Institute). This committee will be evaluating the internship report also.

RESEARCH PROJECT/DISSERTATION

Research Project: Students choosing track 2 shall carry out the research project in their parent Institution only under the guidance of a supervisor assigned by the DLAC.

Dissertation: All categories of students in track 1 are to carry out the dissertation in the Institute they are studying or can work either in any CSIR/Industrial R&D organization/any other reputed Institute which have facilities for dissertation work in the area proposed.

Mark Distribution:

Phase 1: Total marks: 100, only CIA

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
223PXX100	**DISSERTATION PHASE I**	**Project Work**	**0**	**0**	**17**	**11**

COURSE OBJECTIVES:

Dissertation is aimed to bridge the gap between theoretical knowledge and practical application, fostering a well-rounded skill set that prepares students for success in their future engineering careers. Engineering projects often simulate real-world engineering scenarios. This exposure allows students to become familiar with industry practices, standards, and expectations and preparing them for the challenges they might face in their future careers. Depending on the nature of the project, students may acquire practical skills related to specific tools, software, or equipment. This hands-on experience can be highly beneficial when transitioning to a professional engineering role.

Dissertation Phase I can help to identify the problem based on the area of interest through proper literature survey and to foster innovation in design of products, processes or systems based on the identified problem. perform feasibility study by creative thinking and requirement analysis in finding viable solutions to engineering problems

All categories of students in track 1 are to carry out the dissertation in the Institute they are studying or in any CSIR/Industrial/ R&D organization/any other reputed institute which have facilities for dissertation work in the area proposed.

Course Outcomes:

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

CO 1	Identify and define a relevant and significant problem or challenge in the relevant field
CO2	Formulate research methodologies for the innovative and creative solutions
CO 3	Plan and execute tasks utilizing available resources within timelines, following ethical professional and financial norms
CO 4	Organize and communicate technical and scientific findings effectively in written reports, oral presentation, and visual aids

Mapping of course outcomes with program outcomes

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO7**
CO 1	3		3	2	2	3	2
CO 2	3		3	3	3	2	
CO 3	3		2		3	3	2
CO 4		3	3	2			2

Continuous Internal Assessment (CIA) Total Marks: 100

The evaluation committee comprises

1- Project Coordinator(s)
2- A Senior faculty member
3- Supervisor of the student

Pattern:

Zeroth evaluation by the Evaluation Committee	-
Interim evaluation by the Evaluation Committee	20 marks
Final evaluation by the Evaluation Committee	40 marks
Project Phase - I Report (By Evaluation Committee)	20 marks
Project progress evaluation by supervisor	20 marks

The Plagiarism level in the project report shall be less than 25%.

Interim Review

Literature Survey (CO1- 5 marks)
Comprehension and Problem Identification (CO2-5 marks)
Objective Identification (CO2-5 marks)
Document Preparation and Presentation (CO4-5 marks)

Final Review

Literature Survey (CO1-10 marks)
Project Design (CO2-10 marks)
Execution of tasks by utilizing available resources within timelines (CO3 – 10 marks)
Presentation and document preparation (CO4-10 marks)

Evaluation by the supervisor

The guide/supervisor shall monitor the progress being carried out by the student on a regular basis. In case it is found that progress is unsatisfactory it shall be reported to the Department Evaluation Committee for necessary action.

Student's Diary/ Log book: The main purpose of writing diary/log book is to cultivate the habit of documenting and to encourage the students to search for details. The activity diary shall be signed after every week by the supervisor.

The minimum attendance for completing the course is 75%. The pass minimum for the course is 50% for CIA.

SYLLABUS:

DETAILS	HOURS
` 1. Literature study/survey of published literature on the assigned topic 2. Formulation of objectives 3. Formulation of hypothesis/ design/ methodology 4. Formulation of work plan and task allocation. 5. Design documentation 6. Preliminary analysis/Modelling/Simulation/Experiment/Design/Feasibility study 7. Preparation of Phase 1 report	150

Dissertation outside the Institute: For doing dissertation outside the Institution, the following conditions are to be met:

i. They have completed successfully the course work prescribed in the approved curriculum up to the second semester.
ii. The student has to get prior approval from the DLAC and CLAC.
iii. Facilities required for doing the dissertation shall be available in the Organization/Industry (A certificate stating the facilities available in the proposed organization and the time period for which the facilities shall be made available to the student, issued by a competent authority from the Organization/Industry shall be submitted by the student along with the application).
iv. They should have an external as well as an internal supervisor. The internal supervisor should belong to the parent institution and the external supervisor should be Scientists or Engineers from the Institution/Industry/ R&D organization with which the student is associated for doing the dissertation work. The external supervisor shall be with a minimum post graduate degree in the related area.
v. The student has to furnish his /her monthly progress as well as attendance report signed by the external supervisor and submit the same to the concerned Internal supervisor.
vi. The external supervisor is to be preferably present during all the stages of evaluation of the dissertation.

Internship leading to Dissertation: The M. Tech students who after completion of 6 to 8 weeks internship at some reputed organizations are allowed to continue their work as dissertation for the third and fourth semester after getting approval from the CLAC. Such students shall make a brief presentation regarding the work they propose to carry out before the DLAC for a detailed scrutiny and to resolve its suitability for accepting it as an M.Tech dissertation. These students will be continuing as regular students of the Institute in third semester for carrying out all academic requirements as per the curriculum/regulation. However, they will be permitted to complete their dissertation in the Industry/Organization (where they have successfully completed their internship) during fourth semester. They should have an external as well as an internal supervisor. The internal supervisor should belong to the parent institution and the external supervisor should be Scientists or Engineers from the external organization with which the student is associated for doing the dissertation work. The external supervisor shall be with a minimum post graduate degree in the related area. The student has to furnish his /her monthly progress as well as attendance report signed by the external guide and submit the same to the concerned internal guide. The external guide is to be preferably present during all the stages of evaluation of the dissertation.

Dissertation as part of Employment: Students may be permitted to discontinue the programme and take up a job provided they have completed all the courses till second semester (FE status students are not permitted) prescribed in the approved curriculum. The dissertation work can be done during a later period either in the organization where they work if it has R&D facility, or in the Institute. Such students should submit application with details (copy of employment offer, plan of completion of their project etc.) to the Dean (PG) through HoD. The application shall be vetted by CLAC before granting the approval. When the students are planning to do the dissertation work in the organization with R&D facility where they are employed, they shall submit a separate application having following details:

i. Name of R&D Organization/Industry
ii. Name and designation of an external supervisor from the proposed Organization/Industry (Scientists or Engineers with a minimum post graduate degree in the related area) and his/her profile with consent
iii. Name and designation of a faculty member of the Institute as internal supervisor with his/her consent
iv. Letter from the competent authority from the Organization/Industry granting permission to do the dissertation
v. Details of the proposed work
vi. Work plan of completion of project

DLAC will scrutinize the proposal and forward to CLAC for approval. When students are doing dissertation work along with the job in the organization (with R & D facility) where they are employed, the dissertation work shall be completed in four semesters normally (two semesters of dissertation work along with the job may be considered as equivalent to one semester of dissertation work at the Institute). Extensions may be granted based on requests from the student and recommendation of the supervisors such that he/she will complete the M. Tech programme within four years from the date of admission as per the regulation. Method of assessment and grading of the dissertation will be the same as in the case of regular students. The course work in the 3rd semester for such students are to be completed as per the curriculum requirements (i) MOOC can be completed as per the norms mentioned earlier (ii) Audit course are to be carried out either in their parent Institution or by self-learning. However, for self-learning students, all assessments shall be carried out in their parent institution as in the case of regular students.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
224PXX100	**DISSERTATION PHASE II**	**Project Work**	**0**	**0**	**24**	**16**

All categories of students in track 1 are to carry out the DISSERTATION PHASE II in the institute they are studying or in any Industrial/ R&D organization/any other reputed institute which have facilities for dissertation work in the area proposed. DISSERTATION PHASE II shall not compulsorily continuation of DISSERTATION PHASE I. The student has to publish a research article in a conference or a reputed journal before appearing for the end-semester examination. The eligibility criteria for registering to the end semester examination are attendance in the course and no pending disciplinary action. The minimum attendance for appearing for the end semester examination is 75%. Students who do not meet these eligibility criteria are ineligible (identified by FE grade) to appear for the ESE. Students, who have completed a course but could not appear for the end semester examination, shall be awarded 'AB' Grade, provided they meet other eligibility criteria The pass minimum for the course is 45% for ESE and 50% for (CIA and ESE) put together.

Continuous Internal Assessment (CIA) Total Marks: 100

The evaluation committee comprises

1- Project Coordinator(s)
2- A Senior faculty member
3- Supervisor of the student

Pattern (CIA)

Zeroth evaluation by the Evaluation Committee	-
Interim evaluation by the Evaluation Committee	30 marks
Final evaluation by the Evaluation Committee	50 marks
Project progress evaluation by supervisor	20 marks

Evaluation by the supervisor

The guide/supervisor shall monitor the progress being carried out by the student on a regular basis. In case it is found that progress is unsatisfactory it shall be reported to the Department Evaluation Committee for necessary action.

Student's Diary/ Log book: The main purpose of writing diary/log book is to cultivate the habit of documenting and to encourage the students to search for details. The activity diary shall be signed after every week by the supervisor.

End Semester Evaluation (ESE) Total Marks: 100

The evaluation committee comprises

1- Project Coordinator(s)
2- An external expert (from Industry or research/academic institute)
3- Supervisor of the student

Pattern (ESE)

1. **Innovation and Originality (10 marks):**

Assessment of the uniqueness and innovation demonstrated in the project work.
Original contributions, if any, to the field or problem area.

2. **Implementation and Execution (20 marks):**

Evaluation of the actual implementation or execution of the project, including:

Quality of work done
Demonstrated skills and techniques applied
Adherence to project timelines and milestones

3. **Project Documentation (25 marks):**

Comprehensive project report evaluation including:

Introduction and problem statement
Literature review
Methodology and approach
Results and analysis
Conclusion and recommendations
References and citations
Details of the publications
Plagiarism certificate

The Plagiarism level in the project report shall be less than 25%.

4. **Presentation and Defence (40 marks):**

Oral presentation of the project to a panel of examiners, including:

Clarity and effectiveness of the presentation
Ability to explain the project objectives, methodologies, and findings
Handling questions and providing satisfactory answers during the defence

5. **Publication of the work either in a conference or in a journal (5 marks)**

SYLLABUS:

DETAILS	HOURS
` 1. Literature study/survey of published literature on the assigned topic 2. Topic Selection and Proposal 3. Formulation of objectives 4. Research and Planning 5. Formulation of work plan and task allocation. 6. Execution 7. Documentation and Reporting 8. Project Showcase reflecting on the project experience and lessons learned	200

Dissertation outside the Institute: For doing dissertation outside the Institution, the following conditions are to be met:

i. They have completed successfully the course work prescribed in the approved curriculum up to the second semester.
ii. The student has to get prior approval from the DLAC and CLAC.
iii. Facilities required for doing the dissertation shall be available in the Organization/Industry (A certificate stating the facilities available in the proposed organization and the time period for which the facilities shall be made available to the student, issued by a competent authority from the Organization/Industry shall be submitted by the student along with the application).
iv. They should have an external as well as an internal supervisor. The internal supervisor should belong to the parent institution and the external supervisor should be Scientists or Engineers from the Institution/Industry/ R&D organization with which the student is associated for doing the dissertation work. The external supervisor shall be with a minimum post graduate degree in the related area.
v. The student has to furnish his /her monthly progress as well as attendance report signed by the external supervisor and submit the same to the concerned internal supervisor.
vi. The external supervisor is to be preferably present during all the stages of evaluation of the dissertation.