SEMESTER 2

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 mathematical framework for the 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 non-linear 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 of 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	
CO 6							

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**

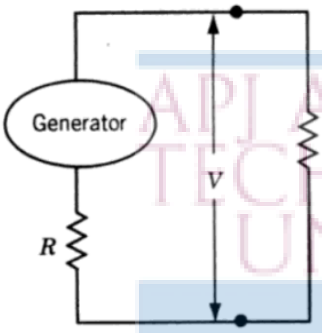
Course Name: **Computational Techniques in Electrical Engineering**

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 $y = \sin x\ (0 \le x \le \pi)$, 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. $$y'' - y = 0, \quad y(0) = 0, y(1) = 1$$
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.



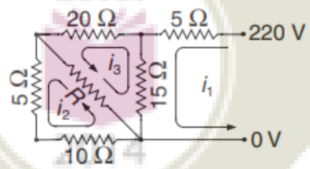
Electric generator with load

5 In which context we can use optimization methods like genetic algorithms and simulated annealing?

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 compute the loop currents i_1, i_2 and i_3 using LU factorization method, for $R = 10\ \boldsymbol{\Omega}$



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 eigen values of the system

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

c. Confirm the estimate by computing y(1) with $h \approx h_{max}/2$ and $h \approx 2\ h_{max}$.

9	Faraday's law characterizes the voltage drop across an inductor as $\boldsymbol{V_L} = \boldsymbol{L}\frac{di}{dt}$, where $\boldsymbol{V_L}$ 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 $2x_1 + x_2 = 4$ $x_1^2 + x_2^2 \leq 40$ $x_1, x_2 \geq 0$ 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 $X_1 = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix}$ using Powell's method.
12	Minimize $f(X) = (x_1 - 1)^2 + (x_2 - 5)^2$ subject to $-x_1^2 + x_2 \leq 4$ $-(x_1 - 2)^2 + x_2 \leq 3$ Starting from the point $X_1 = \begin{Bmatrix} 1 \\ 1 \end{Bmatrix}$ and using Zoutendijk's method. Complete two one-dimensional minimization steps.

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-Siedel iteration – least squares method**;** Eigen value problems - Power method for eigen values – 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

Optimisation problem, Formulation of optimisation problems and 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.

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

Module 5

Nonlinear Programming: Constrained Optimization Techniques 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: 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

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	***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-Siedel iteration – least squares method	2
1.4	Eigenvalue problems - Power method for eigen values – 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	***Constrained non-linear Optimization***	**8 hrs**
4.1	Optimisation *problem, Formulation of optimisation problems and linear optimization - Review only.*	1
4.2	Constrained non-linear Optimization-	1
4.3	Method of Lagrange multiplier, Necessary and sufficient conditions-	2
4.4	Equality and inequality constraints, Kuhn Tucker conditions,	2
4.5	Quadratic programming.	2
5	***Numerical optimization methods***	**8 hrs**
5.1	Direct search methods	2
5.2	Random search-pattern search	2
5.3	Descent Methods-Steepest descent, conjugate gradient.	2
5.4	Powell's method, Fletcher- Reeves method	2

COURSE CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222TEE003	ELECTRIC DRIVES	Program Core	3	0	0	3

Preamble: This course aims to provide knowledge on the electrical drives and their performance analysis

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

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

CO 1	Select a suitable drive for a particular application
CO 2	Analyse the steady state operation and dynamic behaviour of DC and AC drive systems.
CO 3	Design and implement basic algorithms for speed control for DC and AC motors in all four quadrants.
CO 4	Use the concepts learned to further explore and do research on advanced topics in electric drives.

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		
CO 3	3		3	3	3		
CO 4	3		3	3	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 Pattern: 40 marks

Continuous Internal Evaluation: 40 marks
Micro project/Course based project : 20 marks
Course based task/Seminar/Quiz : 10 marks
Test paper, 1 no. : 10 marks
The project shall be done individually. Group projects not permitted. Test paper shall include minimum 80% of the syllabus

End Semester Examination Pattern:

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

Model Question paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M.TECH DEGREE EXAMINATION, MONTH YEAR

Electrical & Electronics Engineering

(Electrical Machines)

222TEE003 Electric Drives

Max. Mark: 60 Duration: 2.5 Hours

PART-A (Answer all questions. Each carries 5 marks)

1. Derive the open loop transfer function of a separately excited dc motor for speed control and obtain the step response due to change in reference voltage.
2. Derive the average value of output voltage of single phase full converter for continuous and discontinuous modes of operation.
3. Explain Static Scherbius drive with a neat diagram.
4. Distinguish between Direct and Indirect vector control scheme and mention the advantages of indirect vector control.
5. Explain vector control of PMBLDC motor.

PART-B (Answer any five questions. Each carries 7 marks)

6. An electric motor has two loads. One has rotational motion coupled through a gear and the other has linear motion coupled through transmission system. Obtain the equivalent moment of inertia of the motor load system and equivalent torque referred to motor shaft.
7. Explain the four quadrant operation of a separately excited dc motor using dual converter in circulating current mode.
8. Draw and explain the implementation of closed loop v/f control strategy with slip compensation for induction motor drive.
9. Explain the concept of space vectors and how can it be used for the speed control of a three phase induction motors.
10. A 440V, 3 phase, 50 Hz, 6 pole, 945 rpm, delta connected induction motor has the following parameters referred to the stator. Rs = Rr' = 2Ω, Xs = 3Ω, Xr' = 4Ω. When driving a fan load at rated voltage it runs at rated speed. The motor speed is controlled by stator voltage control. Determine (i) motor terminal voltage, current and torque at 800 rpm (ii) motor speed, current and torque for a terminal voltage of 280 V.
11. Draw and explain the operation of CSI fed induction motor. Derive the torque equation. Compare VSI and CSI induction motor drives.
12. Draw the closed loop block diagram of self controlled load commutated inverter fed synchronous motor drive and explain the operation.

Syllabus

Module 1

Dynamics of electric drive: Drive system mechanics, Torque equation, Experimental determination of drive system inertia -Steady state characteristics of different types of motors and loads- Stability of drive systems -Separately excited DC machine, dynamic behaviour with constant flux, Closed-loop control of separately excited dc motor, transfer function

Module 2

DC Motor Drives: Two quadrant operation with controlled single-phase and three-phase converters – continuous and discontinuous current operation-Four quadrant operation of dc drives with Dual converter and four-quadrant bridge dc-dc converter - PWM control of four-quadrant dc-dc converter.

Module 3

Induction Motor Drives: Steady state equivalent circuit of 3-phase Induction motor Stator voltage control, Constant v/f speed control with VSI -v/f control with slip compensation, Slip-power recovery schemes – sub synchronous and super synchronous speed operation (Static Kramer and Static Scherbius drives).

Module 4

Vector control of induction motor: Concept of Space Vectors – Basic transformations in reference frame theory - Space Vector Model of Induction motor - Concept of Space Vectors – Basic transformations in reference frame theory - Space Vector Model of Induction motor - Field Orientation Principle- Direct and Indirect vector control - CSI fed induction motor drives

Module 5

Synchronous Motor Drives: VSI fed synchronous motor drives – self controlled synchronous motor - Vector control of synchronous motor

Permanent Magnet Brushless DC Motors – Basic principles and Control schemes – Vector control of Trapezoidal EMF machines

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

No	Topic	No. of Lectures
1	**Dynamics of electric drive**	
1.1	Drive system mechanics	1
1.2	Torque equation, Experimental determination of drive system inertia	2
1.3	Steady state characteristics of different types of motors and loads	1
1.4	Stability of drive systems	1
1.5	Separately excited DC machine, dynamic behaviour with constant flux	2
1.6	Closed-loop control of separately excited dc motor, transfer function	2
2	**DC Motor Drives**	
2.1	Two quadrant operation with controlled single-phase and three-phase converters – continuous and discontinuous current operation	4
2.2	Four quadrant operation of dc drives with Dual converter and four-quadrant bridge dc-dc converter	2
2.3	PWM control of four-quadrant dc-dc converter.	1
3	**Induction Motor Drives**	
3.1	Steady state equivalent circuit of 3-phase Induction motor	2
3.2	Stator voltage control	1

3.3	Constant v/f speed control with VSI -v/f control with slip compensation	2
3.3	Slip-power recovery schemes –sub synchronous and super synchronous speed operation (Static Kramer and Static Scherbius drives).	2
4	**Vector control of induction motor**	
4.1	Concept of Space Vectors – Basic transformations in reference frame theory - Space Vector Model of Induction motor	3
4.2	Field Orientation Principle- Direct and Indirect vector control.	3
4.3	CSI fed induction motor drives	2
5	**Synchronous Motor Drives**	
5.1	VSI fed synchronous motor drives – self controlled synchronous motor	3
5.2	Vector control of synchronous motor	3
5.3	Permanent Magnet Brushless DC Motors – Basic principles and Control schemes – Vector control of Trapezoidal EMF machines	3
		40

Reference Books

1. Werner Leonhard, “Control of Electrical Drives,”, 3rd Ed., Springer
2. R. Krishnan, “Electric Motor Drives: Modeling, Analysis and Control,” Prentice Hall
3. Bimal K. Bose, “Modern Power Electronics and AC Drives,” Prentice Hall
4. G.K. Dubey, “Fundamentals of Electrical Drives,” Narosa

Program Elective 3

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE024	**HYBRID & ELECTRIC VEHICLES**	ELECTIVE 3	3	0	0	3

Preamble:

The main aim of this course is to equip the students with in-depth technical knowledge about the various subsystems in hybrid and electric vehicular systems and carry out designs based on the same. The course details include a detailed study and analysis of drive-train topologies, configuration and control of propulsion systems, energy storage systems and management strategies.

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

CO 1	Familiarise with the various characteristics of conventional vehicles and compare them with hybrid & electric vehicles
CO 2	Analyse the various drive train topologies for hybrid & electric vehicles
CO 3	Analyse the configuration and control of electric propulsion system
CO 4	Analyse the various energy storage systems and energy management strategies
CO 5	Analyse and design the key components related to an electric propulsion system
CO 6	Study about various sensors, actuators, and communication protocols used in vehicles

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

Assessment Pattern

Blooms Category	**End Semester Examination**
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: 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

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 one 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 seven 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

Reg No.:_______________ Name:__________________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
Third Semester M.Tech Degree (R) Examination DEC 2022 (2022 Scheme)

Course Code: **222EEE024**
Course Name: **HYBRID & ELECTRIC VEHICLES**

Max. Marks: 60 Duration: 2.5 Hours

Part A Marks

(Answer all questions)

1. Compare conventional vehicle with hybrid-electric vehicle [5]

2. Describe the factors affecting the performance of batteries used in EVs [5]

3 A PM brushless DC motor has a torque constant of 0.12 Nm/A referred to the DC supply. Estimate the no load speed in RPM when connected to a 48V DC supply [5]

4. Describe about direct measurement of SoC in battery [5]

5. Describe rolling resistance and aerodynamic drag in vehicles [5]

Part B

(Answer any five questions)

6 State and explain the dynamic equation of vehicle motion [7]

7 Explain the different power flow control modes of a typical parallel hybrid system with the help of block diagrams. [7]

8 Draw three different configurations of drive trains in electric vehicles. Briefly explain each configuration. [7]

9 Describe the different battery charging modes? Compare them in detail. [7]

10. An electric vehicle has the following parameters: [7]

m= 1000 kg, C_D=0.2, A_F=2.2m^2, C_0=0.009, C_t=1.6x10^{-6} s^2/m^2

The vehicle is on a level test track. An acceleration test was conducted such that velocity profile is given by 0.2905 t_2, 0≤t≤10 s

(a) Tractive force as function of time for 0≤t≤10 s
(b) Mean tractive power over interval 0≤t≤10 s
(c) Energy loss due to non-conservative forces

11 Describe in detail about the electrical and mechanical constraints to be considered while sizing an electrical machine for an EV [7]

12 A 460V, 60 Hz, six pole, 1176 rpm, Y-connected induction motor has the following parameters referred to the stator at rated condition. [7]

The motor is fed by a six-step inverter The inverter is fed from a battery pac through DC/DC converter The battery pack voltage is 12V, Neglecting all losses,

(a) Determine the output of DC/DC converter
(b) Mention the type of the converter and its conversion ratio

Syllabus

Module 1 (8 hours)

History of hybrid & electric vehicles, Impact of modern drive-trains, Characteristics of conventional vehicles, Drive cycles and their impact on vehicle operation

Module 2 (8 hours)

Hybrid and Electric traction - Basic concepts, drive-train topologies, and power flow control

Module 3 (8 hours)

Introduction to electric components used in hybrid and electric vehicles

EV motors - Introduction, desired features, T-ω characteristics, Configuration and control of various motor drives

Protection schemes for power converters

Module 4 (8 hours)

Energy Storage Systems - Introduction, Battery based energy storage and its analysis, SoC estimation, other advanced storage topologies, Hybridization of different energy storage devices

Energy Management Strategies - Classification and comparison, Implementation issues

Module 5 (8 hours)

Matching the electrical machine and IC engine, Sizing of various components - propulsion motor, power electronic components, energy storage systems

Case studies - Design of Hybrid Electric & Battery Electric Vehicle

Automotive Sensors and Actuators, In-vehicle communication – CAN

Course Plan

No	Topic	No. of Lectures
1	**Introduction to Hybrid & Electric Vehicles**	**(8 hours)**
1.1	History of hybrid & electric vehicles, social and environmental importance of hybrid & electric vehicles, Impact of modern drive-trains on energy supplies	**2**
1.2	Conventional vehicles: Basics of vehicle performance, vehicle power source characterization	1
1.3	Transmission characteristics, mathematical models to describe vehicle performance	4
1.4	Drive cycles and their impact on vehicle operation	1

2	**Hybrid Electric Drive-trains**	**(8 hours)**
2.1	Basic concepts of hybrid traction, introduction to various hybrid drive-train topologies	1
2.2	Power flow control in hybrid drive-train topologies, fuel efficiency analysis	2
2.3	Electric drive-trains: Basic concepts of electric traction	1
2.4	Introduction to various electric drive-train topologies, Power flow control in electric drive-train topologies	4
3	**Electric Propulsion System**	**(8 hours)**
3.1	Introduction to electric components used in hybrid an electric vehicle, Desired features for an EV motor	1
3.2	Introduction to various EV motors, T- ω characteristics	1
3.3	Configuration and control of Brushless DC Motor drives	1
3.4	Configuration and control of Permanent Magnet Synchronous Motor drives	2
3.5	Configuration and control of Induction Motor drives, Configuration and Control of Switched Reluctance Motor drives	2
3.6	Protection schemes for power converters	1
4	**Energy Storage Systems**	**(8 hours)**
4.1	Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis, SoC estimation	2
4.2	Other advanced storage topologies – Super-capacitor based system, Fuel cell based system, Fly wheel based system	2
4.3	Hybridization of different energy storage devices	1
4.4	Introduction to Energy Management Strategies in Hybrid and Electric vehicles, classification and comparison of various strategies	2
4.6	Implementation issues for energy management strategies	1
5	**Sizing of Drive System, In-vehicle Communication**	**(8 hours)**
5.1	Matching the electrical machine and IC engine, Sizing of propulsion motor	1
5.2	Sizing of power electronic components, Selection of energy storage technology	1
5.3	Case studies - Design of Hybrid Electric Vehicle, Design of Battery Electric Vehicle	3
5.4	Automotive Sensors and Actuators, Communication between major components, In-vehicle networks - CAN	3
		40

Reference Books

1. Iqubal Hussein, **Electric and Hybrid Vehicles: Design Fundamentals**, CRC Press

2. Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, **Modern Electric, Hybrid and Fuel Cell Vehicles: Fundamentals**, Theory and Design, CRC Press

3. James Larminie, John Lowry, **Electric Vehicle Technology Explained,** Wiley

4. R. Krishnan, **Permanent Magnet Synchronous and Brushless DC Motors Drives**, CRC Press

5. John G. Hayes, Abas Goodarzi, **Electric Powertrain Energy Systems, Power Electronics and Drives for Hybrid, Electric and Fuel Cell Vehicles**, Wiley

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE027	MODELING AND SIMULATION OF POWER ELECTRONIC SYSTEMS	ELECTIVE 3	3	0	0	3

Preamble:

This course focus on different approaches in modeling of power electronics systems and the use of software tools for analysis

Course Outcomes:

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

CO 1	Develop the model of coil and transformer and realize the model using a suitable simulation tool.
CO 2	Model rotating machines and analyse the performance using a suitable simulation tool.
CO 3	Model power electronic converters using switched models and evaluate the performance using a suitable simulation tool.
CO 4	Formulate the state space averaged model of dc-dc converters and analyse its dynamic behaviour.

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

Assessment Pattern

Bloom's Category	End Semester Examination

Apply	50
Analyse	30
Evaluate	10
Create	10

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed

Original publications (minimum 10 Publications shall be referred): 15 marks

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

Test paper, 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination: 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 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

QP CODE:XXXXX E	**Model Question Paper** **PAGES: 2**	**Slot :**
Reg.No:_____________		Name:

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

Course Code**:** 222EEE027

Course Name: MODELING AND SIMULATION OF POWER ELECTRONIC SYSTEMS

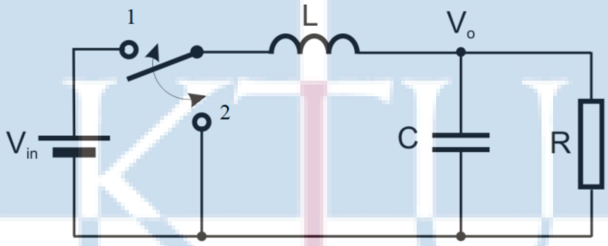
Max. Marks: 60 Hours | **Duration: 2.5**

PART A

Answer all questions

Each question carries 5 marks - 25 marks

1	Derive the generic model of an ideal coil and develop a model block diagram of the same.	5
2	Describe the concept of ITF and construct the model block diagram of a transformer with load alone using ITF	5
3	Explain the algorithm for developing a switched model based on a switched network.	5
4	Derive the switched model of a dc-dc buck converter.	5
5	Explain the concept of averaging based on an averaged switch model.	5
	PART B **Answer any five full questions** **7 marks each - 35 marks**	
6	Describe the generic model of a coil with resistance. Draw the simulink based diagram to realise the above model for a coil with resistance 0.1 ohm and inductance10mH.	7
7	Explain the model of a transformer with magnetizing inductance and thus develop a block	7

	diagram to realize the model	
8	Describe the representation of a four parameter transformer model and draw the simulink model of a four parameter transformer model.	7
9	For a power electronic converter there are two switching states. In state 1, $v_O = V_{in}$ and in state 2, $v_O = V_{in}$, where V_{in} is the dc input and v_O is the output. Derive the switched model of the given converter.	7
10	The switch in given circuit has two states 1 and 2. Out of total time period T, switch remains in state 1 & 2 for T/2 period each.  Develop the model of given circuit using switched modelling method and draw the equivalent circuit.	7
11	Explain the model of a rectifier circuit and draw the equivalent circuit based on the model.	7
12	In a power electronic converter, with a dc input of V_{in} the inductor and capacitor voltage & current are respectively v_L & i_L and v_C & i_C. The circuit equations for the on-time and off-time of the converter are as follows: During t_{on}: $V_i - \frac{di_L}{dt} - v_C = 0$ and $v_C + \frac{dv_C}{dt} - i_L = 0$ During t_{off}: $v_C + \frac{di_L}{dt} = 0$ and $i_L - v_C - \frac{dv_C}{dt} = 0$ Develop the state space average model the converter and draw the equivalent circuit.	7

Syllabus

Module 1 (7 hours):

Modeling of Simple Electro-magnetic Circuits: Generic model of linear inductance (ideal coil) -transient response -Block diagram representation of linear inductance model with excitation function; Generic model of linear inductance with coil resistance -Block diagram representation of model of linear inductance with resistance and excitation function -incorporation of magnetic saturation problem-Block diagram representation of non-linear inductance model with sinusoidal excitation function.

Assignment: Realization of inductor models using Simulink

Module 2 (8 hours):

Modeling of Transformer: Concept of ideal transformer (ITF)- Generic models of ITF-Generic model of transformer with load; Generic model of transformer with load and finite Lm - Block diagram representation of transformer model with load and finite Lm; Generic representation of transformer with magnetizing and leakage inductance- Generic representation of a four parameter transformer model - Block diagram representation of a four parameter transformer model.

Module 3 (10 hours):

Modeling of DC & AC Machines: Modeling of DC Motor-Equivalent circuit of DC motor -Model equations –Block diagram representation of DC Motor model; Modeling of AC Machine -Concept of IRTF model module- model of induction motor using universal IRTF/ITF modules; Switched Models -Concept of switched models- Algorithms to develop switched model; Modeling of single- phase DC-AC inverter using switched model.

Assignment: Realization of DC-AC inverter models using Simulink

Module 4 (10 hours):

Modeling of DC-DC converters based on Switched Model: Derivation of switched model for a dc-dc buck converter in continuous conduction mode- Block diagram representation of dc-dc buck converter using switched model; Switched model for a dc-dc boost converter in continuous conduction mode and dis-continuous conduction mode-Block diagram representation of dc-dc boost converter using switched model; Modeling of AC-DC rectifier using switched model.

Assignment: Dynamic behaviour of the switched model of the ideal buck and boost converter using switched model

Module 5 (8 hours):

State space Modeling and Simulation of DC-DC Converters:Average State-space modeling: Linear circuits – Averaged model of switch;State-space modeling of DC-DC converters:

Buck, boost, buck-boost converters; Small signal modeling and transfer function – Small signal Model of buck converter.

Simulink Assignment -Realization of DC-DC converter models using State-space model

Course Plan

No	Topic	No. of Lectures
1	**Modeling of Simple Electro-magnetic Circuits:**	
1.1	Generic model of linear inductance (ideal coil), transient response.	1
1.2	Block diagram representation of linear inductance model with excitation function.	1
1.3	Generic model of linear inductance with coil resistance	2
1.4	Block diagram representation of model of linear inductance with resistance and excitation function, incorporation of magnetic saturation problem, Block diagram representation of non-linear inductance model with sinusoidal excitation function.	2
1.5	*Assignment: Realization of inductor models using Simulink*	1
2	**Modeling of Transformer:**	
2.1	Concept of ideal transformer (ITF), Generic models of ITF, Generic model of transformer with load,	3
2.2	Generic model of transformer with load and finite *Lm*, Block diagram representation of transformer model with load and finite *Lm*.	2
2.3	Generic representation of transformer with magnetizing and leakage inductance, Generic representation of a four parameter transformer model, Block diagram representation of a four parameter transformer model.	3
3	**Modeling of DC & AC Machines:**	
3.1	Modeling of DC Motor-Equivalent circuit of DC motor, Model equations. Block diagram representation of DC Motor model.	3
3.2	Modeling of AC Machine -Concept of IRTF model module- model of induction motor using universal IRTF/ITF modules	3

3.3	Switched Models -Concept of switched models- Algorithms to develop switched model; Modeling of single- phase DC-AC inverter using switched model.	3
3.4	*Assignment: Realization of DC-AC inverter models using Simulink*	1
4	**Modeling of DC-DC converters based on Switched Model:**	
4.1	Derivation of switched model for a dc-dc buck converter in continuous conduction mode- Block diagram representation of dc-dc buck converter using switched model	3
4.2	Switched model for a dc-dc boost converter in continuous conduction mode and dis-continuous conduction mode-Block diagram representation of dc-dc boost converter using switched model	3
4.3	Modeling of AC-DC rectifier using switched model	3
4.4	*Assignment: Dynamic behaviour of the switched model of the ideal buck and boost converter using switched model*	1
5	**State space Modeling and Simulation of DC-DC Converters**	
5.1	Average State-space modeling: Linear circuits – Averaged model of switch	3
5.2	State-space modeling of DC-DC converters: Buck, boost, buck-boost converters.	2
5.3	Small signal modeling and transfer function – Small signal Model of buck converter	2
5.4	*Simulink Assignment -Realization of DC-DC converter models using State-space model*	1

References

1. Seddik Bacha, Iulian Munteanu, Antoneta Iuliana Bratcu “Power Electronic Converters Modeling and Control with Case Studies” ISSN 1439-2232, ISBN 978-1-4471-5477-8, ISBN 978-1-4471-5478-5 (eBook), Springer London Heidelberg New York Dordrecht

2. André Veltman, Duco W.J. Pulle, and Rik W. De Doncker, “Fundamentals of Electrical Drives”, Second Edition, ISSN 1612-1287 ISSN 1860-4676 (electronic) Power Systems, ISBN 978-3-319-29408-7, ISBN 978-3-319-29409-4 (eBook) , Springer International Publishing Switzerland 2007, 2016

3. V Rajagopalan, “Computer Aided Analysis of Power Electronic Systems”, Marcel Dekker, Inc.

4. Randall Shaffer, “Fundamentals of Power Electronics with MATLAB”, Firewall Media, India

5. Erickson, Maksimovic, “Fundamentals of Power Electronics” - 2nd edition, Springer

6. Mohan, Undeland, Robbins, “Power Electronics”, 3rd edition, John Wiley

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE028	SLIDING MODE CONTROL	ELECTIVE 3	3	0	0	3

Preamble: To familiarize the students with the methodology for the design and implementation of sliding mode controllers for any uncertain plant and to design higher order sliding mode controllers and observers for real time systems.

Course Outcomes:

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

CO 1	Understand the theory of variable structure system
CO 2	Develop Sliding surface and sliding control for the given linear system
CO 3	Design robust nonlinear sliding mode controllers for any uncertain plant
CO 4	Design Discrete time Sliding Mode Control
CO 5	Develop higher order sliding mode controllers.

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

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

End Semester Examination Pattern: 60 Marks

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 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

QP CODE:

PAGES:2

Reg.No:______________

Name:______________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

MONTH & YEAR

Course Code: 222EEE028

Course Name: SLIDING MODE CONTROL

PART A

*(Answer **All** Questions)* (5X5 = 25 Marks)

1. Write down the steps to be followed for designing a sliding mode controller. Also list the main features of sliding mode controllers. **(5)**

2. Design a stabilising variable structure control for a double integrator system **(5)**

3. Explain any one method of designing sliding surface for SMC **(5)**

4. Explain discrete time reaching laws associated with SMC **(5)**

5. Explain the concept of terminal sliding mode control **(5)**

PART B

*(Answer **Any Five** Questions)* (7X5 = 35 Marks)

6. Consider the system $\dot{x} = [\,0 \;\; 1\,;4 \;\; 5\,]\, x + [\,0 \;\; 1\,]\,(u + d)$. Design a stable sliding surface $s = [\,c\,\hat{}T]x = 0$ for the above system **(7)**

7. Explain various methods used to eliminate chattering in sliding mode control **(7)**

8. Consider the dynamical system $\dot{x} = [0 \;\; 1;\, -2 \;\; 3]\;\; x + [0 \;\; 1\,]\,(u + d)$ $y = [1 \;\; 0\,]x$.

Discretize the system using zero order hold technique and then design discrete-time SMC for the system. Select $\tau = 0.1$.?

(7)

9. Explain how integral sliding mode can be designed for a second order chain of integrator system? **(7)**

10. Explain how discrete time sliding mode control can be designed using multirate output feedback **(7)**

11. Explain how sliding mode observer can be employed for a system with unmeasurable state variables? **(7)**

12. Distinguish between twisting algorithm and super twisting algorithms **(7)**

Syllabus

Module I

Introduction to variable structure systems, definition of variable structure and sliding mode, examples of dynamics system with sliding modes
Mathematical background: differential equations with discontinuous right hand sides, solutions in Filippov sense, existence conditions of sliding mode
Concept of a manifold, sliding surface, sliding mode motion and sliding mode control

Module II

Regular form approach-pole placement and LQR method, Properties of sliding mode motion, Reaching laws, method of equivalent control, Chattering problem, approaches of sliding hyper plane designs.

Module III

Discrete time sliding mode control, definition, design methods, Reaching laws of discrete time sliding mode control, Switching and non switching based discrete time sliding mode control

Module IV

Discrete time sliding mode control based on multi rate output feedback techniques. Terminal sliding mode, Integral sliding mode, Design of sliding surface and control law development

Module V

Sliding mode observers-Need of Sliding mode observers- Design of sliding mode observers, Design examples,Introduction to Higher order sliding mode control, twisting controller, super twisting controller

Course Plan

No	Topic	No. of Lectures
1	**Module 1**	
1.1	Introduction to variable structure systems, definition of variable structure and sliding mode, examples of dynamics system with sliding modes. .	2
1.2	Mathematical background: differential equations with discontinuous right-hand sides, solutions in Filippov sense, existence conditions of sliding mode	3
1.3	Concept of a manifold, sliding surface, sliding mode motion and sliding mode control	2
2	**Module II**	
2.1	Regular form approach-pole placement and LQR method,	4
2.2	Properties of sliding mode motion, Reaching laws, method of equivalent control,	2
2.3	Chattering problem, approaches of sliding hyper plane designs.	3
3	**Module III**	
3.1	Discrete time sliding mode control, definition, design methods,	2
3.2	Reaching laws of discrete time sliding mode control	2
3.3	Switching and non switching based discrete time sliding mode control	3
4	**Module IV**	
4.1	Discrete time sliding mode control based on multi rate output feedback techniques.	4
4.2	Terminal sliding mode, Integral sliding mode,	2
4.3	Design of sliding surface and control law development	3
5	**Module V**	
5.1	Sliding mode observers-Need of Sliding mode observers-	2
5.2	Design of sliding mode observers, Design examples	4
5.3	Introduction to Higher order sliding mode control , twisting controller, super twisting controller	2
		40

Reference Books.

1. C. Edwards and S. K. Spurgeon, *Sliding mode control: Theory and applications*. Taylor and Francis; 1998.
2. V. I. Utkin, *Sliding Modes in Control Optimization*. New York: Springer-Verlag; 1992.
3. J. Y. Hung, W. Gao and J. C. Hung, *"Variable structure control: A survey;"* IEEE Transactions on Automatic Control; vol. 40; 1993.
4. Y. W. Weibing Gao and A. Homaifa, *"Discrete-time variable structure control systems*;" IEEE Transactions on Ind. Electronics; vol. 42; no. 2; pp. 117–122; 1995.
5. B. Bandyopadhyay and S. Janardhanan, *Discrete-time Sliding Mode Control*: A Multi-rate Output Feedback Approach,Springer-Verlag; 2005; no. 323.
6. K. Abidi, J. X. Xu, and Y. Xinghuo, "*On the discrete-time integral sliding-mode control*;" IEEE Transactions on Automatic Control; vol. 52; no. 4; pp. 709–715; 2007

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE029	DEEP LEARNING	ELECTIVE 3	3	0	0	3

Preamble:

This course will introduce the theoretical foundations, algorithms, methodologies, and applications of neural networks and deep learning. It will help to design and develop an application-specific deep learning models and also provide the practical knowledge handling and analysing real world applications.

Course Outcomes:

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

CO 1	A student at the end of course should be able to Decide if DL is suitable for a given problem
CO 2	Have a good understanding of the fundamental issues and basics of machine learning
CO 3	Choose appropriate DL algorithm to solve the problem with appropriate hyper parameter
CO 4	Setting Feel comfortable to read and understand DL articles from reputed conferences, journals including NIPS, CVPR, ICCV, ICML, PAMI etc.
CO 5	Outline the concept of the feed forward neural network and its training process
CO 6	Build CNN and Recurrent Neural Network (RNN) models for different use cases

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

(1- Weak, 2-Medium, 3- strong)

Assessment Pattern

Bloom's Category	End Semester Examination (%)
Remember	35
understand	30
Apply	35
Analyse	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed

Original publications (minimum 10 Publications shall be referred): 15 marks

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

Test paper, 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination: 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

QP CODE:

Reg No.:_______________

Name:___________________________ ___

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY SECOND SEMESTER M.TECH. DEGREE EXAMINATION,

MONTH & YEAR

Course Code: 222EEE029

DEEP LEARNING

Max. Marks: 60 Duration: 2.5 hours

PART A

(Answer ***ALL*** questions; each question carries 5 marks)

1. Discuss the different learning approaches used in machine learning
2. Explain the merits and demerits of using Auto encoders in Computer Vision.
3. What is the vanishing gradient problem and exploding gradient problem?
4. Give two benefits of using convolutional layers instead of fully connected ones for visual tasks.
5. Illustrate the workings of the RNN with an example of a single sequence defined on a vocabulary of four words

PART B

(Answer ***any FIVE*** questions; each question carries 7 marks)

6. “A computer program is said to learn from experience E with respect to some class oftasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E.” What is your understanding of the terms task, performance and experience. Explain with two example

7. Compare Boltzmann Machine with Deep Belief Network.

8. Write an algorithm for backpropagation which uses stochastic gradient descent method. Comment on the effect of adding momentum to the network.
9. Draw and explain the architecture of convolutional network ? Input to CNN architecture is a color image of size 112x112x3. The first convolution layer comprises of 64 kernels of size 5x5 applied with a stride of 2 and padding 0. What will be the number of parameters?

10. Explain the working of RNN and discuss how backpropagation through time is used in recurrent networks.

11. Derive update rules for parameters in the multi-layer neural network through the gradient descent.

12. What is the vanishing gradient problem and exploding gradient problem?

****

Syllabus

Module 1

Introduction - What is Deep Learning? – Machine Learning Vs. Deep Learning, representation Learning, Width Vs. Depth of Neural Networks, Activation Functions: RELU, LRELU, ERELU], Boltzmann Machines, Auto Encoders. Optimization Techniques, Gradient Descent, Batch Optimization, Back Propagation - Calculus of Back Propagation

Module 2

Bayesian Learning, Decision Surfaces Linear Classifiers, Machines with Hinge Loss, Unsupervised Training of Neural Networks, Restricted Boltzmann Machines, Auto Encoders. Perceptron and Multi-layer Perceptron – Hebbian Learning - Neural net as an Approximator, Training a neural network - Perceptron learning rule - Empirical Risk Minimization - Optimization by gradient descent

Module 3

Convergence in Neural networks - Rates of Convergence – Loss Surfaces – Learning rate and Data normalization, RMSProp, Adagrad and Momentum , Stochatic Gradient Descent, Acceleration – Overfitting and Regularization, Choosing a Divergence Loss Function – Dropout – Batch Normalization.

Module 4

Convolutional Neural Networks (CNN) - Weights as Templates – Translation Invariance , Training with shared parameters – Arriving at the convolutional model , Mathematical details of CNN, Alexnet – Inception – VGG - Transfer Learning

Module 5

Recurrent Neural Networks (RNNs), Modeling sequences - Back propagation through time - Bidirectional RNNs, Exploding/vanishing gradients - Long Short-Term Memory Units (LSTMs)

Course Plan

No	Topic	No. of Lectures
1	**Introduction to Deep Learning (8)**	
1.1	Introduction - What is Deep Learning? – Machine Learning Vs. Deep Learning, representation Learning	1
1.2	Width Vs. Depth of Neural Networks, Activation Functions: RELU, LRELU, ERELU], Boltzmann Machines, Auto Encoders.	3
1.3	Optimization Techniques, Gradient Descent, Batch Optimization	2
1.4	Back Propagation - Calculus of Back Propagation,	2
2	**Neural Networks (8)**	
2.1	Bayesian Learning, Decision Surfaces Linear Classifiers, Machines with Hinge Loss	2
2.2	Unsupervised Training of Neural Networks, Restricted Boltzmann Machines, Auto Encoders	2
2.3	Perceptron and Multi-layer Perceptron – Hebbian Learning - Neural net as an Approximator	2
2.4	Training a neural network - Perceptron learning rule - Empirical Risk Minimization - Optimization by gradient descent	2
3	**Convergence in Neural networks (8)**	
3.1	Convergence in Neural networks - Rates of Convergence – Loss Surfaces – Learning rate and Data normalization	3
3.2	RMSProp, Adagrad and Momentum , Stochatic Gradient Descent	2
3.3	Acceleration – Overfitting and Regularization	1
3.4	Choosing a Divergence Loss Function – Dropout – Batch Normalization	2
4	**Convolution Neural Network (8)**	
4.1	Convolutional Neural Networks (CNN) - Weights as Templates – Translation Invariance	3
4.2	Training with shared parameters – Arriving at the convolutional model	2
4.3	Mathematical details of CNN	2
4.4	Alexnet – Inception – VGG - Transfer Learning	1

5	**Recurrent Neural Network (8)**	
5.1	Recurrent Neural Networks (RNNs)	2
5.2	Modeling sequences - Back propagation through time - Bidirectional RNNs	3
5.3	Exploding/vanishing gradients - Long Short-Term Memory Units (LSTMs)	3
		40

Reference Books

1. Ian Goodfellow, Yoshua Bengio, Aaron Courville, Deep Learning, Online book, 2017

2. Michael Nielsen, Neural Networks and Deep Learning, Online book, 2016

3. Ian Goodfellow, Yoshua Bengio and Aaron Courville, " Deep Learning", MIT Press, 2017.

4. Josh Patterson, Adam Gibson "Deep Learning: A Practitioner's Approach", O'Reilly Media, 2017

5. Umberto Michelucci "Applied Deep Learning. A Case-based Approach to Understanding Deep Neural Networks" Apress, 2018.

6. Kevin P. Murphy "Machine Learning: A Probabilistic Perspective", The MIT Press, 2012.

7. Ethem Alpaydin,"Introduction to Machine Learning", MIT Press, Prentice Hall of India, Third Edition 2014.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE003	MULTILEVEL INVERTERS AND MODULATION TECHNIQUES	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

PROGRAM OUTCOMES – PO

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

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

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

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

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

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

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

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

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: 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: **CODE222EEE003**

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)

Program Elective 4

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE030	HIGH POWER CONVERTERS AND DRIVES	ELECTIVE4	3	0	0	3

Preamble: This course aims to provide knowledge on the circuit, operation, and performance analysis of various high power converters

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 the performance of high-power rectifiers
CO 2	Analyse the performance of Multilevel inverters
CO 3	Apply suitable modulation techniques for PWM inverters
CO 4	Analyse the performance for medium voltage drives
CO 5	Select a suitable control for induction motor drive
CO 6	

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	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		
CO 6							

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	40%
Analyse	60%
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed

Original publications (minimum 10 Publications shall be referred): 15 marks

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

Test paper, 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: 60 marks

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

Model Question paper

Model Question paper

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

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Branch: **Electrical and Electronics**

Stream(s): **Electrical Machines**

Course Code: **222EEE030** & Name: **HIGH POWER CONVERTERS AND DRIVES**

Max. Marks: 60 Duration : 2.5 hours

Part A

(Answer all questions)

1	Draw the 12-Pulse Series-Type Diode Rectifier and explain its working	5

2	With the help of a circuit diagram, explain the working of Diode-Clamped Multilevel Inverters	5
3	Explain Load-Commutated Inverter.	5
4	Derive the equation for the output voltage of a three-phase two-level voltage source inverter	5
5	With the help of a block diagram explain VSC FED SM Drive with the DTC Scheme	5

Part B

(Answer any five questions)

6.	Draw the circuit diagram and waveforms of the 12-Pulse Series-Type Diode Rectifier and derive the equation of THD and Power factor	7
7.	Explain Space Vector Modulation technique for Diode-Clamped Multilevel Inverters and derive the equation of dwell time.	7
8.	Explain Selective Harmonic Elimination in PWM Current Source Inverters	7
9.	With the help of a circuit diagram and output wave forms, explain the working induction motor drive with Multilevel Cascaded H-Bridge.	7
10.	Explain MTPA control VSC FED synchronous motor	7
11.	Explain dynamic characteristics of High-Power Semiconductor Devices- Silicon Controlled Rectifier (SCR)	7
12.	Explain Diode-Clamped Multilevel Inverters and draw its output waveforms	7

Syllabus

MODULE 1

OVERVIEW OF HIGH-POWER DRIVES- TECHNICAL REQUIREMENTS AND CHALLENGES- Switching Device Constraints- Drive System Requirements - CONVERTER CONFIGURATIONS, INDUSTRIAL MV DRIVES.

High-Power Semiconductor Devices- Silicon Controlled Rectifier (SCR)- Gate Commutated Thyristors- Insulated Gate Bipolar Transistor (IGBT)- Operation of Series Connected Devices- Static and Dynamic Voltage equalisation

Multipulse Diode Rectifiers- Series-Type Multipulse Diode Rectifiers- 12-Pulse Series-Type Diode Rectifier- THD and Power factor - 18-Pulse Series-Type Rectifier, 24 pulse series type rectifier (Block diagrams)

Multipulse SCR rectifiers: Six pulse SCR rectifier - Idealised operation - analysis - THD - Power factor - 12 Pulse SCR rectifier -Idealised operation - Analysis - 18 and 24 pulse rectifiers (Block diagrams only) [10 hrs]

MODULE 2

Cascaded H-Bridge Multilevel Inverters-CHB Inverter with Equal DC Voltage- H-Bridges with Unequal DC Voltages-Carrier-Based PWM Schemes- Diode-Clamped Multilevel Inverters- Converter configuration - Space Vector Modulation Algorithms - Dwell time calculation - Switching sequence design - Inverter output harmonics - Even order harmonics elimination. [6 hrs]

MODULE 3

PWM Current Source Inverters: - Trapezoidal Modulation -Selective Harmonic Elimination- Space Vector Modulation- Parallel Current Source Inverters - Load-Commutated Inverter (LCI)
PWM Current Source Rectifiers: - Single-Bridge Current Source Rectifier- Dual-Bridge Current Source Rectifier- Power Factor Control [8 hrs]

MODULE 4

Voltage Source Inverter Fed Drives: - Two-Level VSI-Based MV Drives- Multilevel Cascaded H-Bridge (CHB) Inverter Fed Drives- /H-Bridge Inverter Fed Drives Current Source Inverter Fed Drives:- CSI Drives with PWM Rectifiers- Transformer less CSI Drive [8 hrs]

MODULE 5

Control of Induction Motor Drives: - Review of Induction Motor Dynamic Models-Review of Field Oriented Control-Direct and Indirect Field Oriented Control -FOC for CSI Fed Drives
Control of Synchronous Motor Drives: - Dynamic Model of Synchronous Motors- VSC FED SM Drive with Zero d-Axis -VSC FED SM Drive with MTPA Control- VSC FED SM Drive with DTC Scheme [8 hrs].

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	**OVERVIEW OF HIGH-POWER DRIVES** [10 hrs]	
1.1	OVERVIEW OF HIGH-POWER DRIVES TECHNICAL REQUIREMENTS AND CHALLENGES	1
1.2	High-Power Semiconductor Devices: Review of Silicon Controlled Rectifier (SCR), Gate Commutated Thyristors, Insulated Gate Bipolar Transistor (IGBT)	2
1.3	Operation of Series Connected Devices: Static and Dynamic Voltage equalisation	1
1.4	Multipulse Diode Rectifiers- Series-Type Multipulse Diode Rectifiers- 12-Pulse Series-Type Diode Rectifier- 18-Pulse Series-Type Rectifier - 24 pulse series type rectifier	2
	Multipulse SCR rectifiers: Six pulse SCR rectifier - Idealised operation - analysis - Line current THD - Effect of source inductance - Power factor	2

	and THD -	
1.5	12 Pulse SCR rectifier -Idealised operation - Analysis - 18 and 24 pulse rectifiers (Block diagrams only)	2
2	**Cascaded H-Bridge Multilevel Inverters** [6 hrs]	
2.1	Cascaded H-Bridge Multilevel Inverters - CHB Inverter with Equal DC Voltage- H-Bridges with Unequal DC Voltages	2
2.2	Carrier-Based PWM Schemes- Neutral point voltage control	1
2.3	Diode-Clamped Multilevel Inverters- Converter configuration - Space Vector Modulation Algorithms - Dwell time calculation - Switching sequence design - Inverter output harmonics - Even order harmonics elimination.	3
3	**PWM Current Source Inverters:** [8 hrs]	
3.1	PWM Current Source Inverters: - Trapezoidal Modulation -Selective Harmonic Elimination	3
3.2	Space Vector Modulation- Parallel Current Source Inverters- - Load-Commutated Inverter (LCI)	3
3.3	PWM Current Source Rectifiers: - Single-Bridge Current Source Rectifier- Dual-Bridge Current Source Rectifier- Power Factor Control	2
4	**Voltage Source Inverter Fed Drives: [**8 hrs]	
4.1	Voltage Source Inverter Fed Drives: - Two-Level VSI-Based MV Drives	2
4.2	Multilevel Cascaded H-Bridge (CHB) Inverter Fed Drives- /H-Bridge Inverter Fed Drive	3
4.3	Current Source Inverter Fed Drives: - CSI Drives with PWM Rectifiers- Transformer less CSI Drive	3
5	**Control of Induction Motor Drives** [8 hrs].	
5.1	Control of Induction Motor Drives: - Induction Motor Dynamic Models-Principle of Field Oriented Control	2
5.2	Direct Field Oriented Control- Indirect Field Oriented Control- FOC for CSI Fed Drives	2
5.3	Control of Synchronous Motor Drives: - Dynamic Model of Synchronous Motors- VSC FED SM Drive with Zero d-Axis Current	2
5.4	VSC FED SM Drive with MTPA Control- VSC FED SM Drive with DTC Scheme	2

Reference Books

1. Bin Wu, Mehdi Narimani – "HIGH-POWER CONVERTERS AND AC DRIVES" Second Edition, IEEE Press, Series on Power Engineering.

2. Ned Mohan, Tore M. Undeland and William P. Robbins- "Power Electronics"– John Wiley & Sons – Second Edition.

3. Daniel W. Hart "Power Electronics", Tata McGraw-Hill Education, 2011

4. John G. Kassakian, Martin F. Schlecht and George C. Verghese, "*Principles*

of Power Electronics", Pearson, 2010.

5. Krishnan R, "*Electric Motor Drives Modeling, Analysis and Control*", Pearson, 2015.
6. Bimal K. Bose, "*Power Electronics and Variable Frequency Drives*", Wiley IEEE Press, 2010.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EE008	**DESIGN OF POWER ELECTRONIC SYSTEMS**	**ELECTIVE 4**	**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

PROGRAM OUTCOMES – PO

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

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

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

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

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

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

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

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

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: 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.

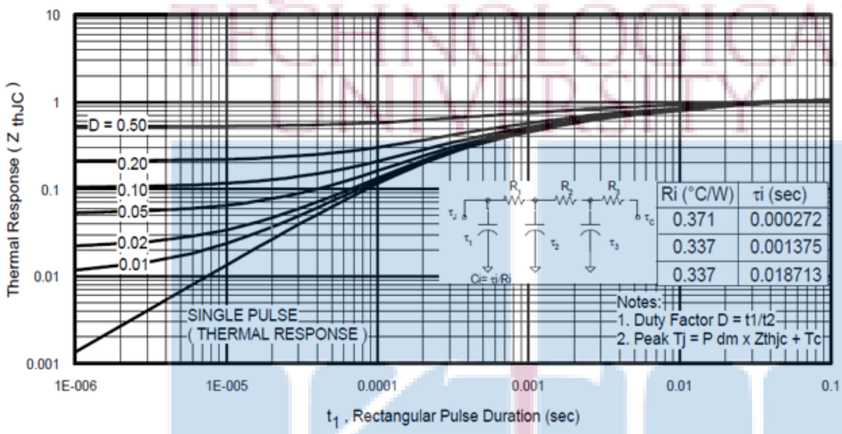
Model Question paper

	Model Question paper	**Slot D**
APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY		
FIRST SEMESTER M.TECH DEGREE EXAMINATION MONTH & YEAR		
Course code: 222EE008	**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).	5	2	2

	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.			
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	3	3	3

	thermal resistance characteristics as shown in figure below. Determine the maximum junction temperature, if the case temperature is 80 ℃.			



	(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 ℃/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	4	5	1

	operating at 50kHz, power being drawn from 230V, 50Hz mains. Identify the possible conducted noise emission sources and explain the means to reduce EMI			
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	CREDIT
222EEE031	**BATTERY MANAGEMENT SYSTEMS FOR EVs.**	**ELECTIVE4**	**3**	**0**	**0**	**3**

Preamble: Nill

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	Illustrate the different types of energy storage systems for electric vehicles.
CO 2	Identify different design and performance parameters of a battery
CO 3	Apply the concepts of the battery management system and design the battery pack.
CO 4	Explain the battery testing, disposal and recycling
CO5	Design and develop a control strategy for EV and HEV using hybrid energy stoarage system consists of battery and fuel cell

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: **40 marks**

Preparing a review article based on peer reviewed

Original publications (minimum 10 Publications shall be referred): 15 marks

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

Test paper, 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: 60 marks

SLOT D

Model Question paper

APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY

M Tech Degree Examination

222EEE031: BATTERY MANAGEMENT SYSTEMS FOR EVs.

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

Part A (Answer all questions)

1. Discuss in detail with a neat diagram the charge and discharge cycle of Li-ion battery. [5]
2. Explain the requirements of HV battery pack. [5]
3. Discuss the importance of cell voltage equalisation. Explain any one method in detail. [5]
4. Explain the effect of SoC and SoC variation on cell aging. [5]
5. Explain the four major steps in the generation of electricity within a fuel cell. [5]

Part B (Answer any 5 questions)

6.
   a) Explain the design issues of NiMH and NiZn batteries in hybrid and battery electric vehicles. [5]
   b) Mention advantages and disadvantages of NiMH and NiZn batteries. [2]
7.
   a) Draw the schematic representation of battery module. Mention the functions of each component. [3]
   b) With block diagrams illustrate the different topologies of battery management system. [4]
8.
   a) Discuss the different types of imbalances in battery cells. [3]
   b) Explain the working of transformer based cell voltage equalizer with neat diagram [4]
9.
   a) What are the factors influencing battery aging. Discuss each in detail. [5]

b) Write short note on battery repurposing. [2]

10.

a) Explain any three fuel cell technologies in detail. [3]

b) Illustrate how fuel cell – battery hybrid storage system can improve the life of battery [4]

11.

a) Compare on board and off board chargers. [4]

b) Explain the advantages and disadvantages of fast charging. [3]

12.

a) Discuss how battery temperature affects its aging. [2]

b) Compare different battery temperature cooling methods that can be used in hybrid/battery electric vehicles. [5]

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).

No	Topic	No. of Lectures
1	**Types of battery for electric vehicles**	
1.1	Introduction-Battery Parameters-Cell and battery voltages, Charge (or AH) capacity, Energy stored, Energy density	2
1.2	Specific power, AH(or charge) efficiency, Energy efficiency,	1
1.3	Self-discharge rates, Battery geometry, Battery temperature	1
1.4	heating and cooling needs, Battery life and number of deep cycles.	1
1.5	Nickel–metal hydride and nickel–zinc batteries for EVs- Technical description of Ni-MH and Ni-Zn batteries- Electrical performance, lifetime	2
1.6	cost of Ni-MH and Ni- Zn batteries- Advantages and disadvantages of Ni-MH and Ni-Zn batteries in EVs-	1
1.7	Design issues-applications -environmental and safety aspects	1
1.8	Lithium-ion batteries for EVs-cell design-pack design- environmental and safety aspects	1
1.9	Lithium-sulfur battery- Lithium-air battery	1

2	**Battery design and performance**	
2.1	Components of HV battery packs- Requirements of HV battery packs,	1
2.2	High-voltage battery management systems (BMS) for electric vehicles- Requirements for HV BMS- Topology of BMS	2
2.3	Design of HV BMS- Cell balancing, battery state estimation	1
2.4	Safety aspects of battery management systems for electric vehicles	1
2.5	Thermal management of batteries for electric vehicles- Motivation for battery thermal management	2
2.6	Heat sources sinks, and thermal balance- Design aspects of thermal management systems	2
3	**Battery management system**	
3.1	Voltage cell battery equlisation- resistive, inductive, capacitive eqaulisers-	1
3.2	Cuk equalisers-transformer based equalisers- importance of battery cell equalization	2
3.3	Charging Architectures for Electric and Plug-In Hybrid Electric Vehicles- different configurations-onboard chargers	2
3.4	Dedicated converter- integrated converter-	1
3.5	Off board chargers- Dedicated Off-Board DC Chargers- Challenges for Fast Charging Stations- EV / PHEV charging Standards	2
4	**Aging and repurposing**	
4.1	Aging effects- Aging mechanisms and root causes	1
4.2	Aging of battery packs- Testing- Diagnostic methods	1
4.3	Extension of battery lifetime	1
4.4	Repurposing of batteries from electric vehicles-problem being addressed-Advantages of battery repurposing	2
4.5	Computer simulation for battery design and lifetime-introduction-essentials of modeling approach	2
5	**Application of fuel cells in EVs and HEVs**	
5.1	Operation principles of fuel cells-characteristics.	1
5.2	Fuel cell technologies- Proton Exchange Membrane Fuel Cells- Alkaline Fuel Cells	1
5.3	Phosphoric Acid Fuel Cells - Molten Carbonate Fuel Cells- Solid Oxide Fuel Cells-Direct Methanol Fuel.	1
5.4	Fuel supply-Hydrogen production and storage-non hydrogen fuel cells.	1
5.5	Fuel Cell Hybrid Electric Drive train Design-configuration-control strategy-parametric design	2

5.6	Fuel cell – battery based hybrid energy storage system – control strategies	2
		43

Reference Books

1. Bruno Scrosati, Jürgen Garcheand Werner Tillmetz, Advances in Battery Technologies for Electric Vehicles ISBN 978-1-78242-398-0

2. Mehrdad Ehsani,Yimin Gao,Stefano Longo,Kambiz M. Ebrahimi Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, CRC press,3 rd-Edition, ISBN: 978-1-4987-6177-2 (Hardback)

3.James Larminie Oxford Brookes University, Oxford, UK John Lowry Acenti Designs Ltd., UK, Electric Vehicle Technology Explained

4.C.C Chan, K.T Chau: Modern Electric Vehicle Technology, Oxford University Press Inc., New York 2001.

5.Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.

6.Gregory L. Plett, Battery Management Systems vol-1,vol-2 ISBN-13: 978-1-63081-023-8, ISBN-13: 978-1-63081-027-6

7.Selected Articles Published by MDPI, Emerging Technologies for Electric and Hybrid Vehicles, ISBN 978-3-03897-191-7 (PDF)

8.Sheldon S. Williamson, Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles,Springer, ISBN 978-1-4614-7711-2 (eBook)

9.HILDA BRIDGES, HYBRID VEHICLES AND HYBRID ELECTRIC VEHICLESNEW DEVELOPMENTS, ENERGY MANAGEMENT AND EMERGING TECHNOLOGIES, Nova Science Publishers, Inc.

10.Ottorino Veneri, Technologies and Applications for Smart Charging of Electric and Plug-in Hybrid Vehicles, springer, ISBN 978-3-319-43651-7 (eBook)

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE006	DIGITAL CONTROL SYSTEM DESIGN	ELECTIVE4	3	0	0	3

Preamble: Nill

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	3 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.

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 **D**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION

MONTH & YEAR

Branch: **Electrical &Electronics Engineering**

Course Code & Name: 222EEE006 **DIGITAL CONTROL SYSTEM DESIGN**

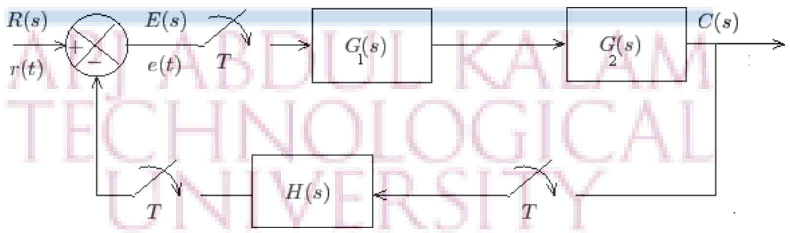
Answer *all*questions from part A and
any five questions from part B.
Limit answers to the required points.

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 5

$$G(z) = \frac{K(0.3679z + 0.2542)}{(z - 0.3679)(z - 1)}.$$

function is Determine the value of K for stability by use of Jury'sstability test. Also determine the frequency of oscillations at the output

4. Explain controllability & observability of digital systems. 5

5. Consider a multi output linear system described by the state model 5

$x(k + 1) = Fx(k) + Gu(k)$

$y(k) = Cx(k) - Du(k)$

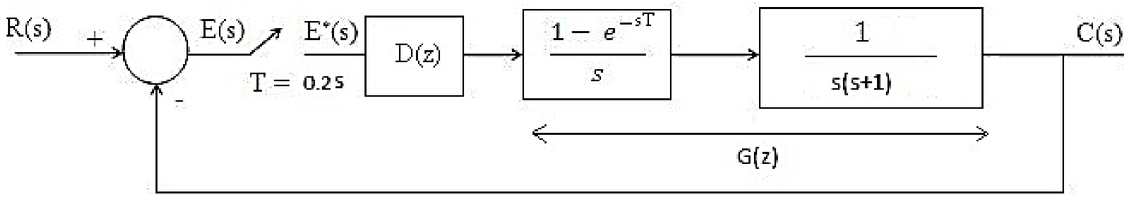
where,

$$F = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -2 & 1 & -1 \end{bmatrix}, G = \begin{bmatrix} 0 & 1 \\ 1 & 0 \\ 1 & 1 \end{bmatrix}, C = \begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix}, D = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

Check whether the system is observable

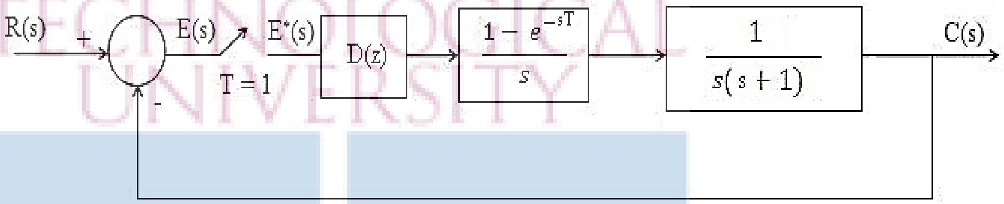
PART B

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 7

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.



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 7

$$x(k+1) = Gx(k) + Hu(k)$$
$$y(k) = Cx(k)$$

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

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 and Corse Plan

No	Topic	No. of Lectures (40)
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
222EEE026	ENERGY STORAGE SYSTEMS	ELECTIVE4	3	0	0	3

Preamble: This course provides an introduction to energy storage technologies and equips the students to select suitable energy storage systems for various industrial applications.

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

CO 1	Illustrate different types of energy storage systems.
CO 2	Select battery packs to suit customer requirements.
CO 3	Apply the theory of ultra capacitors for energy storage.
CO 4	Compare different fuel cell technologies for energy storage.
CO 5	Select energy storage systems for electric vehicles, micro-grids and 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	2					
CO 2	3	2	2	3	2	2	
CO 3	3	2	3	3		2	
CO 4	3	2		3			
CO 5	3	2	2	3	2		

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed

Original publications (minimum 10 Publications shall be referred): 15 marks

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

Test paper, 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.

Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to 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 carry7 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

SLOT D

QP CODE: PAGES: 2

Reg.No:______________ Name:______________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 222EEE026

Course Name: Energy Storage Systems

Max. Marks: 100 Duration: 3 Hours

PART A (5 x 5 = 25 Marks)

Answer all Questions. Each question carries 5 Marks

1. Compare the different energy storage techniques citing applications for each type.
2. A battery has capacity of 4000mAh and a C rating of 10C, then calculate the maximum current the battery can deliver.

3.Compare the characteristics of Ultra Capacitors with batteries.

4. Discuss about the major requirements for an electrolyte in a fuel cell.
5. Illustrate the technical requirements for energy storage systems in micro-grids and smart grids?

PART B (5 x 7 = 35 Marks)

Answer any five Questions. Each question carries 7 Marks

6. Explain the different types of chemical energy storage systems.
7. Suppose a Battery Life is defined as 2000 cycles when used in standard conditions. The standard conditions are "charged at 0.5C, discharged at 1 C at 25°C with 0.85 DoD". Assume that one cycle is counted as 1+x, whenever standard operating conditions are violated. Assume,

(a) x is 0.25 for every degree variation in temperature (T) from 25°C

(b) x is 0.5 for every 0.01 increment of DoD (ie., D) from 0.85

(c) x is 0.1 for every % increment of charge rate (C) from 0.5C and

(d) x is 0.05 for every % increment of discharge rate (D) from 1C.

Determine the life-cycle of the battery when C, D, T and H are 1.5C, 3C, 45 °C and 0.95 respectively.

8. Explain with a neat figure, the principle of operation of ultra capacitors. Draw the equivalent circuit and explain.

9. List out and discuss the technologies for hydrogen storage.

10. Compare the different hybrid energy storage systems for EVs.

11. Portray the fuel cell reactions with alkaline / acid / molten carbonate / ceramic electrolytes and in Methanol fuel cells.

12. Design a 15kWh battery pack with nominal voltage of 350V using Li Ion cells of 3.65V, 14Ah. Show how the cells are arranged to build the best configuration for the battery. What will be the battery voltage when its SoC is (i) 100% and (ii) 0%?

Syllabus:

Module 1 (6 Hrs)

Need of energy storage - different types of energy storage; Potential energy - pumped hydro storage; Compressed gas system- compressed air energy storage; Kinetic energy - Flywheel storage operation - principles of flywheels - power capacity of flywheel systems -flywheel technologies; Fossil fuels and synthetic fuels; Solar ponds for energy storage; Electrical and magnetic energy storage - capacitors - electromagnets; Chemical energy storage - Thermo-chemical, photo-chemical, bio-chemical, electro-chemical systems; Comparison of energy storage technologies; Hybridization of energy storages.

Fundamental concepts of batteries - Primary and secondary batteries - electrochemical reactions - thermodynamic voltage - battery equivalent circuit.

Module 2 (11 Hrs)

Battery parameters - storage density - energy density - energy efficiency - charge efficiency, specific energy - specific power - state of charge (SoC) - state of health (SoH) - state of function (SoF); Measurement of battery performance; Factors affecting battery cell life cycles - C rate - depth of discharge (DoD).

Battery Technologies - Lead-acid batteries - Nickel-based batteries: Nickel/iron, nickel/cadmium, nickel–metal hydride (Ni–MH) - applications - Lithium-based batteries: Lithium–polymer (Li–P), Lithium-ion (Li-Ion), Lithium-Cobalt, Lithium Manganese Oxide, Lithium Iron Phosphate (LiFP), Lithium Nickel Manganese Cobalt Oxide (NMC), Lithium Nickel Cobalt Aluminium Oxide (NCA), Lithium Titanate - Applications.

Battery pack development process - Electrical design of battery pack - busbar design; Battery cell testing - testing standards -safety issues; Charging and discharging of a battery - Charge / Discharge characteristics.

Module 3 (7 Hrs)

Magnetic and Electric Energy Storage Systems:

Superconducting magnetic energy storage (SMES) systems; Capacitors; Ultra-capacitor - Basic principles - equivalent circuit.

Ultra-capacitor technologies: Electrochemical double layer capacitor (EDLC) - principle of working - structure - performance and applications; Role of activated carbon and carbon nano-tubes in performance enhancement; Comparison of Ultra-capacitor characteristics with batteries - applications.

Module 4 (10 Hrs)

Fuel Cells: Operating principle of fuel cells: Electrode potential and current–voltage curve

Fuel cell reactions with alkaline / acid / molten carbonate / ceramic electrolytes / Methanol fuel cells; Fuel cell system characteristics; Circuit model

Hydrogen as energy carrier - Hydrogen storage - Hydrogen production: Compressed hydrogen, cryogenic liquid hydrogen, metal hydrides.

Fuel cell technologies: Alkaline fuel cells (AFC), Phosphoric acid fuel cells (PAFC)

Molten carbonate fuel cells (MCFC), Solid oxide fuel cells (SOFC), Non-hydrogen fuel cells, Direct methanol fuel cells (DMFC), Proton exchange membrane (PEM) fuel cells, Rechargeable fuel cells, Applications.

Hybrid fuel cell-battery systems - hybrid fuel cell-supercapacitor systems.

Module 5 (6 Hrs)

Energy storage systems for electric vehicles: Mechanical - electrochemical - chemical - electrical and thermal storage systems.

Hybrid energy storage systems: Configurations and applications - Backup energy supply (PV array).

Standards for EV batteries: IS 17855: 2022 / ISO 12405-4: 2018.

Energy Storage in Micro-Grids and Smart Grids: Technical requirements - Round-trip efficiency - response time - lifetime and cycling - sizing - operation and maintenance - use cases.

Frequency regulation; Renewable energy integration; peak shaving and load levelling.

Energy management with storage systems; Battery SCADA; Enhancement of energy conversion efficiency by introducing energy storage.

Course Plan:

No	Topic	No. of Lectures
1	**Module 1 (6 Hrs)**	
1.1	Need of energy storage, different types of energy storage.	1

	Potential energy: Pumped hydro storage. Compressed gas system: Compressed air energy storage.	
1.2	Kinetic energy: Flywheel storage operation, principles of flywheels, power capacity of flywheel systems, flywheel technologies.	1
1.3	Fossil fuels and synthetic fuels, Solar ponds for energy storage	1
1.4	Electrical and magnetic energy storage: Capacitors, electromagnets.	1
1.5	Chemical energy storage: Thermo-chemical, photo-chemical, bio-chemical, electro-chemical systems.	1
1.6	Comparison of energy storage technologies, Hybridization of energy storages.	1
2	**Module 2 (11 Hrs)**	
2.1	Fundamental concepts of batteries: Primary and Secondary batteries, Electrochemical reactions, Thermodynamic voltage, Battery Equivalent circuit.	1
2.2	Battery parameters - storage density, energy density, energy efficiency, charge efficiency, specific energy, specific power, state of charge (SoC), state of health (SoH), state of function (SoF), Measurement of battery performance.	1
2.3	Factors affecting battery cell life cycles - C rate, depth of discharge (DoD)	1
2.4	Battery Technologies: Lead-acid batteries, Nickel-based batteries-Nickel/iron, nickel/cadmium, nickel–metal hydride (Ni–MH), Applications.	1
2.5	Lithium-based batteries: Lithium–polymer (Li–P), lithium-ion (Li-Ion).	1
2.6	Lithium-Cobalt, Lithium Manganese Oxide, Lithium Iron Phosphate (LiFP)	1
2.7	Lithium Nickel Manganese Cobalt Oxide (NMC), Lithium Nickel Cobalt Aluminium Oxide (NCA), Lithium Titanate, Applications	1
2.8	Battery pack development process - Electrical design of battery pack, busbar design.	2

2.9	Battery cell testing, Testing standards, Safety issues.	1
2.10	Charging and discharging of a battery, Charge / Discharge characteristics.	1
3	**Module 3 (7 Hrs)**	
3.1	**Magnetic and Electric Energy Storage Systems:** Superconducting magnetic energy storage (SMES) systems, Capacitors.	2
3.2	Ultra-capacitor: Basic principles, equivalent circuit.	1
3.3	Ultra-capacitor technologies: Electrochemical double layer capacitor (EDLC), principle of working, structure, performance and applications,	2
3.4	Role of activated carbon and carbon nano-tubes in performance enhancement.	1
3.5	Comparison of Ultra-capacitor characteristics with batteries - applications	1
4	**Module 4 (10 Hrs)**	
4.1	**Fuel Cells:** Operating principle of fuel cells: Electrode potential and current–voltage curve	1
4.2	Fuel cell reactions with alkaline / acid / molten carbonate / ceramic electrolytes / Methanol fuel cells, Fuel cell system characteristics, Circuit model	1
4.3	Hydrogen as energy carrier, Hydrogen storage, Hydrogen production: Compressed hydrogen, cryogenic liquid hydrogen, metal hydrides.	2
4.4	Fuel cell technologies:, alkaline fuel cells (AFC), Phosphoric acid fuel cells (PAFC)	1
4.5	Molten carbonate fuel cells (MCFC), Solid oxide fuel cells (SOFC)	1
4.6	Non-hydrogen fuel cells, Direct methanol fuel cells (DMFC), Proton exchange membrane (PEM) fuel cells.	1
4.7	Rechargeable fuel cells, Applications	1
4.8	Hybrid fuel cell-battery systems, hybrid fuel cell-supercapacitor	2

	systems.	
5	**Module 5 (6 Hrs)**	
5.1	Energy storage systems for electric vehicles: Mechanical, electrochemical, chemical, electrical and thermal storage systems.	1
5.2	Hybrid energy storage systems: Configurations and applications, Backup energy supply (PV array).	1
5.3	Standards for EV batteries: IS 17855: 2022 / ISO 12405-4: 2018.	1
5.4	Energy Storage in Micro-Grids and Smart Grids: Technical requirements: Round-trip efficiency, response time, lifetime and cycling, sizing, operation and maintenance, use cases	1
5.5	Frequency regulation, renewable energy integration, peak shaving and load levelling.	1
5.6	Energy management with storage systems, Battery SCADA, Enhancement of energy conversion efficiency by introducing energy storage.	1

40

Text Books:

[1] T R Crompton, "Battery Reference Book", Reed Educational and Professional Publishing Ltd., 2000.

[2] James Larminie and John Lowry, "Electric Vehicle Technology Explained", John Wiley & Sons Ltd., 2003.

[3] John Warner, "The Handbook of Lithium Ion Battery Pack Design", Elsevier Inc., 2015.

[4] Aldo V Da Rosa, "Fundamentals of Renewable Energy Processes", Elsevier Academic Press, 2005.

References:

[1] Handbook on Battery Energy Storage System, Asian Development Bank, December 2018.

[2] Iqbal Hussain, "Electric and Hybrid Vehicles – Design fundamentals", CRC Press,

2021.

[3] Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay, Ali Emadi, “Modern Electric, Hybrid Electric, and Fuel Cell Vehicles”, CRC Press, 2005.

[4] Ali Emadi, “Handbook of Automotive Power Electronics and Motor Drives”, Taylor & Francis, 2005.

[5] C C Chan and K T Chau, “Modern Electric Vehicle Technology”, Oxford University Press, 2001.

[6] Ali Emadi, “Advance Electric Drive Vehicles”, CRC Press, 2015.

[7] NPTEL Lecture notes - “Introduction to Hybrid and Electric Vehicles - Module 9: Energy Storage” https: //nptel.ac.in/content/storage2/courses/108103009/download/M9.pdf

[8] NPTEL Video Lecture 03: “Supercapacitors” https://archive.nptel.ac.in/courses/113/105/113105102/

[9] NPTEL Video Lecture: Battery pack development, Part 2: https://www.youtube.com/watch?v=ArkO0u1Q3co

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE033	ADVANCED INSTRUMENTATION	ELECTIVE4	3	0	0	3

Preamble:

This course enables the learners to understand the advanced concept in instrumentation system. This course includes basic understanding of instrumentation, transducers, fiber optic sensors, and laser instrumentation. This course includes the Concepts in Virtual Instrumentation and Intelligent controllers

Course Outcomes:

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

CO 1	Acquire sound knowledge in advanced Instrumentation and Control Engineering with ability to provide appropriate solution to problems related to various instrumentation system
CO 2	Familiarize the concepts of fiber optic sensors and its applications
CO 3	Apply the principle of Lasers and develop laser-based measuring instrumentation system.
CO 4	Identify laser instrumentation in the biomedical field.
CO 5	Learn and apply computing platform and Engineering software tools for solving problems related to Process Control, Automation, Measurement and Control etc.
CO6	To acquire Concepts in Virtual Instrumentation

Mapping of course outcomes with program outcomes

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

(1- Weak, 2-Medium, 3- strong)

Assessment Pattern

Bloom's Category	**End Semester Examination(%)**
Remember	15
Understand	20
Apply	25
Analyse	
Evaluate	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

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

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students).

Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to 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:

Reg No.:_______________

Name:_____________________________ ___

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY SECOND SEMESTER M.TECH. DEGREE EXAMINATION,

MONTH & YEAR

Course Code: 222EEE033

ADVANCED INSTRUMENTATION

Max. Marks: 60 Duration: 2.5 hours

PART A

(Answer *ALL* questions; each question carries 5 marks)

1. Draw and explain Least square calibration curves.
2. Explain the measurements of current using fiber optic sensors?
3. What is the principle of Q-switching? Mention its advantages
4. Describe different medical applications of lasers.
5. List out the importance of the neuro fuzzy controller in other fields.

PART B

(Answer ***any FIVE*** questions; each question carries 7 marks)

1. Explain the factors that govern the dynamic characteristics of instruments.
2. Describe different applications of integrated optic fiber technology.
3. What is the use of fiber optic gyroscope? Explain its working with neat diagram
4. Explain the measurement of acceleration using lasers.
5. Draw and explain the block diagram of a biomedical instrumentation system.
6. Draw the architecture of Virtual Instruments. and mention the characteristics and advantages of VI.
7. Explain with neat sketches, how the ANN can be used for process identification.

****

Syllabus

Module 1

General concepts and terminology of measurement systems, static and dynamic characteristics, errors, standards and calibration. Least square calibration curves, Calibration accuracy, installed accuracy, Effect of measurement error on quality control decision in manufacturing, Review of Transducers, Principles of operations and its classification, Characteristics. Silicon sensors for the measurement of pressure, Level, Flow and Temperature, Bio-sensors, types and its application.

Module 2

Fiber optic sensors, intensity modulated sensors, microbend strain intensity modulated sensor, liquid level types hybrid sensor, internal effect intensity modulated sensor, phase sensor, diffraction grating sensors, sensors using single mode fiber.
Fabry-Perot fiber optic sensors, Electric field and voltage sensors, Chemical fiber optic gyroscopes, magnetic field and current fiber sensor. Military and aerospace applications, important applications of integrated optic fiber technology.

Module 3
Fundamental characteristics of laser-three level and four level lasers, laser modes, resonator configuration-q switching and mode locking-cavity dumping types of lasers. Measurement of length, distance, velocity, acceleration, current, voltage and atmospheric effects using laser.

Laser Safety: Radiation hazards, maximum permissible exposure, classification, safety measures and Personal Protective Equipment (PPE).

Module 4

Development of Biomedical Instrumentation, biometrics, Sources of bioelectric potentials, resting and action potentials. Propagation of action potentials bioelectric potentials-examples (ECG, EEG, EMG, ERG, EOG, EGG). Biopotential electrodes, theory, microelectrodes, skin surface electrodes-needle electrodes biochemical transducers. Laser application in machine:

Laser- Pulsed Ruby Laser, Nd- AG laser, Argon Laser, C02 laser, Helium-neon laser, applications, Advantages of laser surgery Laser based Doppler blood flow meter, Endoscope, Cardio scope Laparoscope -Endoscopic laser coagulator cryogenic surgery. Medical thermography- Physics of thermography

Module 5

Introduction about Intelligent controllers, Model based controllers, Predictive control, Artificial Intelligent Based Systems, Experts Controller. Fuzzy Logic System and Controller, Artificial Neural Networks, Neuro-Fuzzy Control system, Applications. Virtual Instrumentation: Architecture of Virtual Instruments, Data Flow technique, Graphical

Programming in data flow. Development of virtual instruments using graphical user Interface

Corse Plan

No	Topic	No. of Lectures
1	**General concepts and terminology of measurement systems (8)**	
1.1	General concepts and terminology of measurement systems, static and dynamic characteristics, errors, standards and calibration	2
1.2	Least square calibration curves, Calibration accuracy, installed accuracy	1
1.3	Effect of measurement error on quality control decision in manufacturing	1
1.4	Review of Transducers, Principles of operations and its classification, Characteristics.	2
1.5	Silicon sensors for the measurement of pressure, Level, Flow and Temperature, Bio-sensors, types and its application	2
2	**Optical Fiber Sensors and Optical Fiber Sensor Applications (8)**	
2.1	Fiber optic sensors, intensity modulated sensors, microbend strain intensity modulated sensor, liquid level types hybrid sensor, internal effect intensity modulated sensor, phase sensor, diffraction grating sensors, sensors using single mode fiber	3
2.2	Fabry-Perot fiber optic sensors, Electric field and voltage sensors, Chemical fiber optic gyroscopes, magnetic field and current fiber sensor	3
2.3	military and aerospace applications, important applications of integrated optic fiber technology	2
3	**Laser Instrumentation (7)**	
3.1	Fundamental characteristics of laser-three level and four level lasers, laser modes	1
3.2	Resonator configuration-q switching and mode locking-cavity dumping types of lasers.	1
3.3	Measurement of length, distance, velocity, acceleration, current, voltage and atmospheric effects using laser	2
3.4	Laser Safety: Radiation hazards, maximum permissible exposure, classification, safety measures and Personal Protective Equipment (PPE).	3
4	**Biomedical Instrumentation (9)**	
4.1	Development of Biomedical Instrumentation, biometrics, Sources of bioelectric potentials, resting and action potentials	1

4.2	Propagation of action potentials bioelectric potentials- examples (ECG, EEG, EMG, ERG, EOG, EGG)	2
4.3	Biopotential electrodes, theory, microelectrodes, skin surface electrodes-needle electrodes biochemical transducers	1
4.4	Laser application in machine: Laser- Pulsed Ruby Laser, Nd- AG laser, Argon Laser, C02 laser, Helium-neon laser, applications, Advantages of laser surgery	2
4.5	Laser based Doppler blood flow meter, Endoscope, Cardio scope Laparoscope -Endoscopic laser coagulator cryogenic surgery	2
4.6	Medical thermography- Physics of thermography	1
5	**Introduction about Intelligent controllers (8)**	
5.1	Introduction about Intelligent controllers, Model based controllers, Predictive control, Artificial Intelligent Based Systems, Experts Controller	2
5.2	Fuzzy Logic System and Controller, Artificial Neural Networks, Neuro-Fuzzy Control system, Applications.	3
5.3	Virtual Instrumentation: Architecture of Virtual Instruments, Data Flow technique, Graphical Programming in data flow	2
5.4	Development of virtual instruments using graphical user Interface	1

40

Reference Books

1 Sawhney A.K., A course in Electrical and Electronic Measurements & instrumentation, DhanpatRai.

2 Govind P. Agrawal, Fiber-Optic Communication Systems, 4th Edition, Wiley publication, 2010.

3. S.Nagabhushana and N.Sathyanarayana, Lasers and Optical Instrumentation, I.K.International publishing, 2010.

4. Jovitha Jerome, Virtual Instrumentation using LabVIEW, , Eastern Economy edition, PHI learning private Ltd., 2010

5. Dale E. Seborg, Thomas F. Edgar, Duncan A. Melli Champ, Process Dynamics and Control, Second Edition, Wiley-India, 2011

Industry /

Interdisciplinary

Elective

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE070	**Energy Efficiency in Electrical Systems**	**INTERDISCIPLINARY ELECTIVE**	**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: 40 marks

Preparing a review article based on peer reviewed

Original publications (minimum 10 publications shall be referred) : 15 marks

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

Test paper, 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: 60 marks

The end semester 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 Code: 222EEE070

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	2

	organizations at centre and state level responsible for its implementation.	
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.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE071	Electric Charging Systems For Electrical Vehicles	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: 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. 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 Electrical 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

40

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: 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.

Model Question paper

QP Code:

Name:

Reg No:

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

EIGHTH SEMESTER M. TECH DEGREE

EXAMINATION, MONTH & YEAR

Course Code: 22EEE072

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:	**2**

Pyrheliometer

Sunshine recorder

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,	2

	Direct PV-battery connection, Charge controller	
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
		40

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

Mini Project

COURSE CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222PEE100	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	

Electric Drives Lab

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222LEE002	ELECTRIC DRIVES LAB	LAB	0	0	2	1

Preamble: This Laboratory Course provides a platform for modeling and analysis of Electric drives and their performance analysis with the help of hardware and software tools.

Prerequisite: Basic knowledge of machines and power electronics theory and simulation tools

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

CO 1	Develop simulation models of open loop and closed loop speed control of DC motors and induction motor using modern simulation tools.
CO 2	Develop control algorithms in digital control platforms such as Microcontrollers, DSP and FPGA for the control of motor drives.
CO 3	Develop simulation models of open loop and closed loop DC-DC convertors using modern simulation tools.
CO 4	Acquire sufficient experimental skills to carry out independent experimental research.
CO 5	
CO 6	

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

Assessment Pattern

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

Continuous Internal Evaluation Pattern: 100 Marks

Practical Records /outputs- 40%
Regular Class Viva-Voce -20%
Final Assessment - 40%

LIST OF EXPERIMENTS (A minimum of 10 experiments are mandatory)

Hardware Experiments:

1. Speed control of control of converter fed DC motor Drives
2. Speed control of control of chopper fed DC motor drives

3. Speed control of 3-phase induction motor.
4. Use of Microcontrollers for control of AC motor & DC motor drive
5. Use of DSP for control of AC motor & DC motor drive
6. Use of FPGA for control of AC motor & DC motor drive
7. Position and speed control of a Permanent Magnet Synchronous motor.

Simulation Experiments:

1. Simulation of open loop & closed loop Speed Control of DC motor drive (using MATLAB/SIMULINK)
2. Simulation of open loop & closed loop Voltage Source Inverter fed three phase Induction Motor drive (using MATLAB/SIMULINK).
3. Simulation of Vector Control of three phase Induction motor drive (using MATLAB/SIMULINK)
4. Simulation of sine PWM & space vector PWM
5. Simulation of 3-phase induction motor drive using V/f control
6. Voltage and Current monitoring using LABVIEW
7. Simulation of a Switched Reluctance Motor Drive.
8. Control Experiments using LABVIEW
9. Design Experiments using MAXWELL
10. Simulation of closed loop control of DC-DC converters.