SEMESTER II

Discipline: ELECTRICAL & ELECTRONICS

Stream: EE3 (POWER SYSTEMS & POWER ELECTRONICS, POWER SYSTEMS, POWER SYSTEMS & CONTROL)

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**

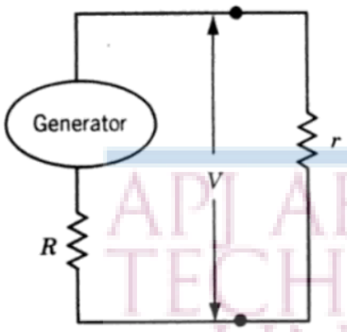
Course Name: **Computational Techniques in Electrical Engineering**

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 $y = \sin x \ (0 \leq x \leq \pi)$, determine the value of $y(\frac{\pi}{6})$ using the cubic spline approximation.
3	Solve the boundary value problem defined below using finite difference method. Compare the solution obtained at y(0.5) with the exact value for h=0.5 and h=0.25. $$y'' - y = 0, \ \ y(0) = 0, y(1) = 1$$
4	An electric generator has an internal resistance of R ohms and develops an open circuit voltage of V volts. Find the value of the load resistance r for which power delivered by the generator will be a maximum.



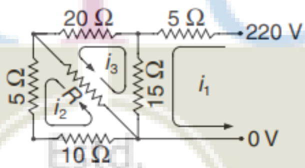
Electric generator with load

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 $V_L = L\frac{di}{dt}$, where V_L is the voltage drop (V), L is the inductance (in henrys (H)), i is the current (in Amps), and 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.

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

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

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222TEE002	POWER SYSTEM OPERATION AND CONTROL	Program Core	3	0	0	3

Preamble: This course is intended to give an insight into the economic operation of interconnected power systems with various types of energy sources ensuring security of the system.

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

CO 1	Operate a power system with number of thermal generators with minimum cost
CO 2	Operate a power system with proper hydro-thermal coordination considering the limits on energy supply
CO 3	Evaluate the secure operation of a power system considering the possible contingencies
CO 4	Operate an interconnected power system optimally with proper energy trading among utilities
CO 5	Operate an interconnected power system optimally respecting the energy trade contracts and regulations on frequency and voltage

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

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

Continuous Internal Evaluation: 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: 60 marks

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

Model Question paper

QP CODE:

Reg. No:_______________ Name:_________________

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

Course Code: 222TEE002

Course Name: POWER SYSTEM OPERATION AND CONTROL

Max. Marks: 60 Duration: 2.5 Hrs

PART A

Answer all questions. Each Question Carries 5 marks (5 x 5 =25 marks)

1. Compare unit commitment problem with economic load dispatch
2. Explain long range hydro scheduling
3. Describe about contingency analysis of power system
4. Explain the interchange evaluation with unit commitment in the context of interchange of power and energy
5. Describe about voltage control using (a) mid-line boosters and (b) transformer taps

PART B

Answer any Five full questions. Each question carries 7 marks (5 x 7= 35 marks)

6. Explain priority list method of solving unit commitment problem.

7. The fuel cost functions in \$/MWh of three generating units are given below. Find an economic operating point for these units using λ iteration method for two iterations. The total load on the system is 2500 MW. Assume λ start =8 \$/MWh and Δλ = 10% of λ start

$$F_1(P_1) = 749.55 + 6.950\,P_1 + 9.680 \times 10^{-4}\,P_1^2$$

$$F_2(P_2) = 1285.0 + 7.051\,P_2 + 7.375 \times 10^{-4}\,P_2^2$$

$$F_3(P_3) = 1531.0 + 6.531\,P_3 + 1.040 \times 10^{-3}\,P_3^2$$

$320\text{ MW} \le P_1 \le 800\text{ MW}$, $300\text{ MW} \le P_2 \le 1200\text{ MW}$ and $275\text{ MW} \le P_3 \le 1100\text{ MW}$

8. Assume a system with 'N ' normally fuelled thermal plants plus one turbine generator fuelled under a 'take-or-pay' agreement. Discuss about the economic dispatch of the system.

9. What are linear sensitivity factors? How are they utilised for contingency analysis of power systems?

10. Four areas are interconnected. Each area has a total generation capacity of 1000 MW currently on-line. Area loads for a given hour are L_1=400 MW, L_2=350 MW, L_3=550 MW, and L_4=450 MW. The transmission lines are each sufficient to transfer any amount of power required. The composite input-output production cost characteristics of each area are as follows:

$F_1 = 200 + 2\,P_1 + 0.005\,P_1^2$ \$/h

$F_2 = 325 + 3\,P_2 + 0.002143\,P_2^2$ \$/h

$F_3 = 275 + 2.6\,P_3 + 0.003091\,P_3^2$ \$/h

$F_4 = 190 + 3.1\,P_4 + 0.00233\,P_4^2$ \$/h

In all cases, $140\text{ MW} \le P_i \le 1000\text{ MW}$. Find the cost of each area if each independently supplies its own load, and the total cost for all four areas.

11. With block diagrams, explain the following functions of AGC (a) supplementary control action and (b) tie-line control

12. A two area power system connected by a tie-line has the following parameters on a 100 MVA common base.

Parameters	Area 1	Area 2
Speed regulation	R_1 =0.05	R_2 =0.0625
Freq. sensitive load coefficient	D_1 =0.6	D_2 =0.9
Inertia constant	H_1 =5	H_2 =4
Base power	1000 MVA	1000 MVA

Governor time constant	T_{g1} =0.2 s	T_{g2} =0.3 s
Turbine time constant	T_{t1} =0.5 s	T_{t2} =0.6 s

The units are operating in parallel at the nominal frequency of 50 Hz. The synchronising power coefficient computed from the initial operating condition is 2 p.u. A load change of 187.5 MW occurs in area 1.

(a) determine the new steady state frequency and the change in tie line flow.

(b) account the changes in frequency, load, generation, and tie line flow.

Syllabus and Course Plan

Syllabus

Module 1 (8 Hours)

Unit Commitment and Economic Load Dispatch: Introduction to unit commitment, constraints in unit commitment- Unit commitment solution methods-Priority List method, Lagrange relaxation solution-The economic dispatch problem- The lambda iteration method- Economic Dispatch via binary search- Base Point and Participation Factor method- Composite Generation Production Cost Function

Module 2 (8 Hours)

Generation with Limited Energy Supply and hydrothermal scheduling: Introduction to fuel scheduling - Take-or-Pay Fuel Supply Contract- Hard limits and slack variables- Introduction to hydrothermal coordination – Long range and short-range hydro scheduling- Types of Scheduling Problems – Scheduling Energy- Hydrothermal Scheduling Problem with storage limitations- Pumped-Storage Hydro-Scheduling with a λ-γ iteration

Module 3 (8 Hours)

Power system security: Introduction to power system security- Contingency analysis and detection of network problems- An overview of security analysis - Linear Sensitivity Factors - Power Transfer Distribution Factors - Line Outage Distribution Factors- Voltage collapse - AC Power Flow Methods - Contingency Selection

Module 4 (8 Hours)

Optimal power flow, **interchange of energy and pooling:** The optimal power flow calculation combining economic dispatch and the power flow- Optimal power flow using the dc power flow-Solution of the ACOPF- Inter change contracts -Energy, Dynamic Energy, Contingent, Market Based, Transmission use, Reliability - Energy interchange between utilities- Inter utility economy energy evaluation - Interchange evaluation with unit commitment

Module 5 (8 Hours)

Control of Generation: Review of Automatic Generation Control (AGC)- Supplementary control and Tie line control- AGC implementation- AGC Features- Modelling exercise using SIMULINK- Voltage control using transformer and mid-line boosters- AGC including excitation system

Course Plan

No	Topic	No. of Lectures
I	**Unit Commitment and Economic Load Dispatch**	

1.1	Introduction to unit commitment, constraints in unit commitment	1
1.2	Unit commitment solution methods-Priority List method, Lagrange relaxation solution	3
1.3	The economic dispatch problem- The lambda iteration method- Economic Dispatch via binary search- Base Point and Participation Factor method	3
1.4	Composite Generation Production Cost Function	1
2	**Generation with Limited Energy Supply and hydrothermal scheduling**	
2.1	Introduction to fuel scheduling - Take-or-Pay Fuel Supply Contract- Hard limits and slack variables	2
2.2	Introduction to hydrothermal coordination – Long range and short-range hydro scheduling	1
2.3	Types of Scheduling Problems – Scheduling Energy	1
2.4	Hydrothermal Scheduling Problem with storage limitations	2
2.5	Pumped-Storage Hydro-Scheduling with a λ-γ iteration	2
3	**Power system security**	
3.1	Introduction to power system security	1
3.2	Contingency analysis and detection of network problems	2
3.3	An overview of security analysis - Linear Sensitivity Factors - Power Transfer Distribution Factors - Line Outage Distribution Factors	3
3.4	Voltage collapse - AC Power Flow Methods - Contingency Selection	2
4	**Optimal power flow, interchange of energy and pooling**	
4.1	The optimal power flow calculation combining economic dispatch and the power flow	2
4.2	Optimal power flow using the dc power flow	1
4.3	Solution of the ACOPF	1
4.4	Inter change contracts -Energy, Dynamic Energy, Contingent, Market Based, Transmission use, Reliability	2
4.5	Energy interchange between utilities	1
4.6	Inter utility economy energy evaluation - Interchange evaluation with unit commitment	1
5	**Control of Generation**	
5.1	Review of Automatic Generation Control (AGC)	1
5.2	Supplementary control and Tie line control	1
5.3	AGC implementation- AGC Features	2
5.4	Modelling exercise using SIMULINK	1
5.6	Voltage control using transformer and mid-line boosters	1
5.7	AGC including excitation system	2

Text Books

1. Allen J.Wood, Wollenberg B.F., “Power Generation Operation and Control”, John Wiley & Sons, Second Edition, 1996.

2. S S. Vadhera, “Power System Analysis and Stability”, Khanna Publishers

3. Kirchmayer L.K., “Economic Control of Interconnected Systems”, John Wiley & Sons, 1959.

Reference Books

1. Nagrath, I.J. and Kothari D.P., “Modern Power System Analysis”, TMH, New Delhi, 2006.

2. B. M. Weedy, “Electric Power Systems”, John Wiley and Sons, New York, 1987

3. A Monticelli., “State Estimation in Electric Power System-A Generalised Approach”

4. Ali Abur& Antonio Gomez Exposito, Marcel Dekkerjnc, “Power System State EstimationTheory and Implementation”.

5. Hadi Sadat, “Power System Analysis”, Tata McGraw-Hill 9. Recent literature.

PROGRAM ELECTIVE 3

222EEE012	EMBEDDED PROCESSORS AND CONTROLLERS	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 3	3	0	0	3

Preamble: Nil

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

CO 1	Design real time embedded systems by analysing the characteristics of different computing elements in embedded system.
CO 2	Identify the unique characteristics of real time operating systems and evaluate the need for real time operating system
CO 3	Identify and characterize architecture of ARM MCU
CO 4	Apply the knowledge gained for Programming ARM Processor for different applications.
CO 5	Analyse various examples of embedded systems based on ARM processor.

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		

Assessment Pattern

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

Mark distribution

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

Continuous Internal Evaluation Pattern:

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

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

Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:
The end semester examination will be conducted by the respective College.

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

Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.

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

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

Model Question Paper

Pages **SLOT**

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

STREAM:

221EIA002- EMBEDDED SYSTEMS AND APPLICATIONS

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

	Part A **(Answer all questions)**	**Marks**
1	Differentiate between independent design and codesign concepts	(5)
2	Illustrate with examples the advantages of writing embedded firmware in C.	(5)
3	Compare features of various ARM architectures	(5)
4	Generate an asymmetric square wave at four pins of PORT P0 using software delay	(5)
5	Develop a block schematic diagram for implementing vison-controlled ROBOT application and explain each block	(5)
	Part B **(Answer any five questions)**	
6	Choose appropriate hardware units needed for the following embedded applications a) Robot b) Motor Control and c) Digital camera. Justify your answer,	(7)
7	With a flow chart model illustrate the embedded program development process from high level language to machine level language	(7)
8	Analyse the distinct features of real time operating system that makes it suitable for embedded applications	(7)
9	With the help of a neat diagram explain the architecture ARM processor	(7)
10	Generate PWMs at the six output pins of PWM unit with duty cycles of 40 and 50%	(7)
11	Design an embedded system for Adaptive cruise control and explain the details	(7)
12	Write an embedded C program to interface a single switch and display its status through a relay, Buzzer and LED	(7)

Syllabus

Module 1

Embedded System Organization

Embedded computing – characteristics of embedded computing applications – Introduction to embedded system design- architecture embedded system - Overview of Processors and hardware units in an embedded system – Selection of processor, Memory- I/O devices,Communication protocols SPI, I2C, CAN etc.

Embedded system design and development process- Embedded System On Chip(SOC)- Build process- Challenges in embedded system design, optimising design metrices- Hardware software co-design- Design technologies, Design examples

Software Tools, IDE, Linking and Locating software, Choosing the right platform-Testing, Simulation Debugging Techniques and Tools, Laboratory Tools and target hardware debugging, Emulators

Module 2

Embedded Programming Concepts and RTOS

Programming Concepts -Assembly language, C program elements, Macros and functions, data types data structures Loops and Pointers Object oriented Programming, Embedded programming in C++

Operating System Basics, Types of Operating Systems, Real Time Operating System, Tasks, Process and Threads, Multi processing and Multi-tasking

RTOS Task scheduling models, Handling of task scheduling and latency and deadlines as performance metrics, Co-operative Round Robin Scheduling, Case Studies of Programming with RTOS

Module 3

Architecture and Programming of ARM

Introduction to ARM core architectures, ARM extension, family, Pipeline, memory management, Bus architecture, Programming model, Registers, Operating modes, instruction set, Addressing modes, memory interface.

Programming of ARM, Read Write Memory Access, Basic programming using Online/Offline platforms

Module 4

On Chip Peripherals and Interfacing Lpc2148

Internal Architecture of ARM LPC 2148, Study of on-chip peripherals – Input/ output ports, Timers, Interrupts, on-chip ADC, DAC, RTC modules, WDT,PLL, PWM,USB, I2C, SPI, CAN etc

Programming GPPIO, Timer programming, PWM Unit programming ARM 9 ,ARM Cortex -M3

Module 5

Embedded Control Applications -Case Studies

Embedded Controller Programmable interface with A/D & D/A interface; Digital voltmeter, -PWM motor speed controller, serial communication interface Feedback control system, relay control unit, driving electrical appliances like motors, bulb, pump, etc.

Case Studies- Embedded system in automobile, Adaptive cruise control, Vison controlled Robot, Ball following Robot

Course Project: Develop an embedded control application using ARM Platform

Course Plan

No	Topic	No. of Lectures
1	**Embedded System Organization (8 hours)**	
1.1	Embedded computing – characteristics of embedded computing applications – Introduction to embedded system design- architecture embedded system - Overview of Processors and hardware units in an embedded system – Selection of processor, Memory- I/O devices	2
1.2	Communication protocols SPI, I2C, CAN etc.	1
1.3	Embedded system design and development process -Embedded System On Chip(SOC),Build process, Challenges in embedded system design, optimising design metrices, Hardware software co-design, Design technologies, design examples	2
1.4	Software Tools, IDE, Linking and Locating software, Choosing the right platform	1
1.5	Testing, Simulation Debugging Techniques and Tools, Laboratory Tools and target hardware debugging, Emulators	2
2	**Programming Concepts and RTOS(8 hours)**	
2.1	Programming Concepts -Assembly language, C program elements, Macros and functions, data types data structures Loops and Pointers.	1
2.2	Object oriented Programming, Embedded programming in C++ and JAVA	1
2.3	Operating System Basics, Types of Operating Systems, Real Time Operating System(RTOS), Tasks, Process and Threads, Multi processing and Multi-tasking	2
2.4	RTOS Task scheduling models, Handling of task scheduling and latency and deadlines as performance metrics	2
2.5	Co-operative Round Robin Scheduling, Case Studies of Programming with RTOS	2
3	**Architecture and Programming of ARM (8 hours)**	
3.1	Features and Architecture of ARM, RISC vs CISC, Modes of operation	2
3.2	ARM assembly language, Addressing Modes, Instruction set	2
3,3	Programming of ARM, ALP, C, Basic programming using Online/Offline platforms	2
3.4	Read Write Memory Access, Multiple register load and store	2
4	**Peripheral programming of ARM((8 hours)**	
4.1	Internal Architecture and features of ARM LPC 214X family	2
4.2	Peripherals inside the chip, GPIO, Timer, Interrupt, UART,PWM	2
4.3	Programming GPPIO, Timer programming	2
4.4	PWM Unit programming, ARM 9, ARM Cortex -M3	2
5	**Embedded Control Applications -Case Studies (8 hours)**	

5.1	Embedded Controller Programmable interface with A/D & D/A interface, Digital voltmeter, -PWM motor speed controller, serial communication interface	2
5.2	Feedback control system, relay control unit, driving electrical appliances like motors, bulb, pump, etc.	2
5.3	Case study -Embedded system in automobile, Adaptive cruise control	2
5.4	Case study -Vison controlled Robot, Ball following Robot	2

Reference Books

1. Jonathan Valvano, Embedded Microcomputer Systems Real Time Interfacing, Third Edition Cengage Learning, 2012

2. Raj Kamal, Embedded Systems-Architecture, programming and design, 3rd edition, TMH.2017

3. Lyla B Das, Embedded Systems an Integrated Approach, Pearson, 2013

4. David E. Simon, An Embedded Software Primer‖, Pearson Education,2000.

5. Steve Heath, Butterworth Heinenann, Embedded systems design: Real world design Newton mass USA 2002

222EEE013	POWER CONVERSION TECHNIQUES IN POWER SYSTEMS	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 3	3	0	0	3

Preamble:

To impart knowledge about the power electronic converters and their control methods.

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

CO 1	Analyze the operation of isolated dc-dc converter in continuous and discontinuous conduction mode
CO 2	Explain the operation and control of single phase ac voltage controller
CO 3	Analyze the performance and switching schemes of Voltage Source Inverters and Current Source Inverters
CO 4	Explain the operation of Inverters for off-grid and grid connected systems
CO 5	Explain the concepts of Multilevel inverters and resonant converters.

Mapping of course outcomes with program outcomes

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

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:

*Continuous Internal Evaluation**: 40 marks***

Preparing a review article based on peer reviewed

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

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

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

End Semester Examination Pattern:

*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:

Reg. No:______________ Name:________________

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

Course Code: 222EEE013

Course Name: POWER CONVERSION TECHNIQUES IN POWER SYSTEMS

Max. Marks: 60 Duration: 2.5 Hrs

PART A

Answer all questions. Each Question Carries 5 marks **Marks**

1.	Derive the expression for output voltage of a forward converter with relevant waveforms.	(5)
2.	Compare unipolar & bipolar switching in single phase Sine PWM inverter.	(5)
3.	With circuit diagram and waveforms, explain the capacitor commutated CSI with resistive load.	(5)
4.	Draw the circuit diagram and explain the operation of ZVS resonant converter.	(5)
5.	With necessary diagrams, explain the inverters used for grid connected PV systems.	(5)

PART B

Answer any Five full questions. Each question carries 7 marks

6.	a)	Derive the expression for the output voltage of flyback converter operating in continuous conduction mode with circuit diagram and necessary waveforms.	(4)
	b)	A single-phase full-wave ac voltage controller feeds a load of R = 20Ω with an input voltage of 230 V, 50 Hz. Firing angle for both the thyristors is 45°. Calculate (a) rms value of output voltage (b) load power and input pf	(3)
7.		With circuit diagram and waveforms, explain two stage sequence control of single-phase ac voltage controllers with R load.	(7)
8.		With circuit diagram and waveforms, explain the three-phase VSI in 180˚ conduction mode with R load. Derive the expression for fundamental voltages.	(7)
9.		Explain space vector modulation for inverters. Derive the expression to calculate dwell times.	(7)

10. With neat circuit diagram and waveforms, explain the operation of single phase auto-sequential commutated CSI feeding pure inductive load. (7)

11. a) Draw the circuit diagram and waveforms of full bridge series resonant inverter with unidirectional switches. Explain its principle of operation. (4)

    b) Compare ZVS and ZCS resonant converters. (3)

12. a) Explain the principle of operation of a cascaded Multilevel Inverter with a neat circuit diagram. (4)

    b) Draw the circuit diagram of bidirectional inverter for PV system and explain its operation. (3)

Syllabus

Module 1 (8 Hours):

Isolated dc-dc converters and AC voltage controllers: Steady-state analysis of fly back, forward, push-pull and bridge topologies-Analysis of single-phase ac voltage controller with R and RL load- Two stage sequence control of single-phase ac voltage controllers - R and RL load

Module 2 (9 Hours):

Switched Mode Inverters: Voltage Source Inverters (VSI) - single phase half-bridge, full bridge and three-phase bridge inverter with R load - Stepped wave operation-THD in output voltage of single phase and three phase VSI-Pulse width modulation – Single pulse width, Multiple pulse width and Sine-triangle PWM (unipolar & bipolar modulation) – Harmonic Profile

Module 3 (7 Hours):

Space Vector PWM and Current source inverter: Space Vector PWM, Evaluation of dwell times- Current Source Inverter(CSI): Analysis of capacitor commutated CSI with resistive load - Analysis of single phase auto-sequential commutated CSI feeding pure inductive loads-Three phase auto-sequential commutated CSI – commutation process.

Module 4 (8 Hours):

Resonant Converters: Principle - Series resonant inverter circuit with unidirectional and bidirectional switches –half bridge and full bridge configurations -Zero Current Switching Resonant switch converters: L type and M type-Zero voltage switching resonant converter, Comparison of ZVS and ZCS converters

Module 5 (8 Hours):

Application of Power Electronics in Solar PV systems: Introduction to off-grid and grid connected systems - Inverters for off-grid and grid connected systems - Bidirectional Inverter – principle-Multilevel inverter – diode clamped, flying capacitor and cascaded multilevel inverter topologies

Course Plan

No	Topic	No. of Lectures
1	**Isolated dc-dc converters and AC voltage controllers:**	
1.1	Steady-state analysis of fly back, forward, push-pull and bridge topologies.	3
1.2	Analysis of single-phase ac voltage controller with R and RL load	3
1.3	Two stage sequence control of single-phase ac voltage controllers - R and RL load	2
2	**Switched Mode Inverters:**	
2.1	Voltage Source Inverters (VSI) - single phase half-bridge, full bridge and three-phase bridge inverter with R load - Stepped wave operation	3
2.2	THD in output voltage of single phase and three phase VSI	3
2.3	Pulse width modulation – Single pulse width, Multiple pulse width and Sine-triangle PWM (unipolar & bipolar modulation) – Harmonic Profile	3
3	**Space Vector PWM and Current source inverter:**	
3.1	Space Vector PWM, Evaluation of dwell times	3
3.2	Current Source Inverter(CSI): Analysis of capacitor commutated CSI with resistive load - Analysis of single phase auto-sequential commutated CSI feeding pure inductive loads	3
3.3	Three phase auto-sequential commutated CSI –commutation process.	1
4	**Resonant Converters:**	
4.1	Principle - Series resonant inverter circuit with unidirectional and bidirectional switches –half bridge and full bridge configurations	4
4.2	Zero Current Switching Resonant switch converters: L type and M type.	2
4.3	Zero voltage switching resonant converter, Comparison of ZVS and ZCS converters	2
5	**Application of Power Electronics in Solar PV systems:**	
5.1	Introduction to off-grid and grid connected systems	2
5.2	Inverters for off-grid and grid connected systems - Bidirectional Inverter – principle	2
5.3	Multilevel inverter – diode clamped, flying capacitor and cascaded multilevel inverter topologies	4

Text Books

1. Ned Mohan, et. al., "Power Electronics: Converters, Design and Applications," Wiley
2. V. Ramanarayanan, "Course Notes on Switched Mode Power Converters, "Department of Electrical Engineering, Indian Institute of Science, Bangalore
3. L. Umanand, "Power Electronics: Essentials and Applications," Wiley, 2009

Reference Books

1. G. K. Dubey, et.al., "Thyristorised Power Controllers," New Age International
2. JosephVithayathil, "Power Electronics: Principles and Applications", Tata McGraw Hill
3. Muhammad. H. Rashid, "Power Electronics Handbook – Devices, Circuits & Applications", Elsevier
4. Thimothy L. Skvarenina, "The Power electronics handbook", CRC press, 2002
5. Daniel W. Hart, Power Electronics, McGrawHill, 2011
6. Muhammad H. Rashid, "Power Electronics Devices, Circuits, and Applications", PHI.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE027	**MODELING AND SIMULATION OF POWER ELECTRONIC SYSTEMS**	Program 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**
Internal exam 1 no	**10 marks**

End Semester Examination Pattern:

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

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

Model Question paper

Model Question Paper

PAGES: 2

QP CODE:XXXXX **Slot : E**

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

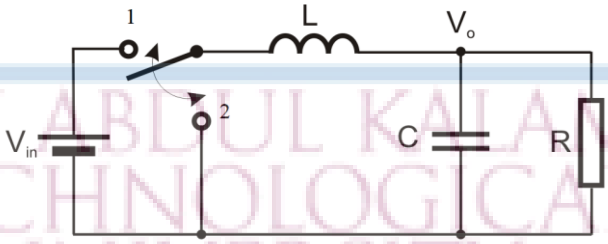
Max. Marks: 60 **Duration: 2.5 Hours**

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 diagram to realize the model	7
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

Text Books

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

References Books

1. V Rajagopalan, "Computer Aided Analysis of Power Electronic Systems", Marcel Dekker, Inc.
2. Randall Shaffer, "Fundamentals of Power Electronics with MATLAB", Firewall Media, India
3. Erickson, Maksimovic, "Fundamentals of Power Electronics" - 2nd edition, Springer
4. Mohan, Undeland, Robbins, "Power Electronics", 3rd edition, John Wiley

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE015	CONTROL TECHNIQUES FOR POWER ELECTRONIC SYSTEMS	PROGRAM ELECTIVE 3	3	0	0	3

Preamble: This course provides a general approach to develop Pulse-width modulation (PWM) strategies for power converters and equips the students to select suitable PWM scheme based on the desired performance indices.

Course Outcomes:

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

CO 1	Develop different power electronic converters starting from the ideal switch model.
CO 2	Analyse different carrier-based PWM techniques for voltage control of power converters.
CO 3	Design and analyze different space vector PWM schemes applied to 3-phase VSI and evaluate in terms of performance indices.
CO 4	Analyze overmodulation strategies for power converters.
CO 5	Analyse the operation of different multilevel inverter topologies and its PWM control.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: 40 marks

Preparing a review article based on peer reviewed Original publications

(minimum 10 Publications shall be referred) : 15 marks

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

Test paper, 1 no. : 10 marks

(Test paper shall include minimum 80%)

End Semester Examination Pattern:

End Semester Examination: 60 marks

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

		Slot: C
QP CODE:		**PAGES: 2**
Reg.No:______________		Name:______

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

Course Code**: 222EEE015**

Course Name: **CONTROL TECHNIQUES FOR POWER ELECTRONIC SYSTEMS**

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

PART A

Answer all questions

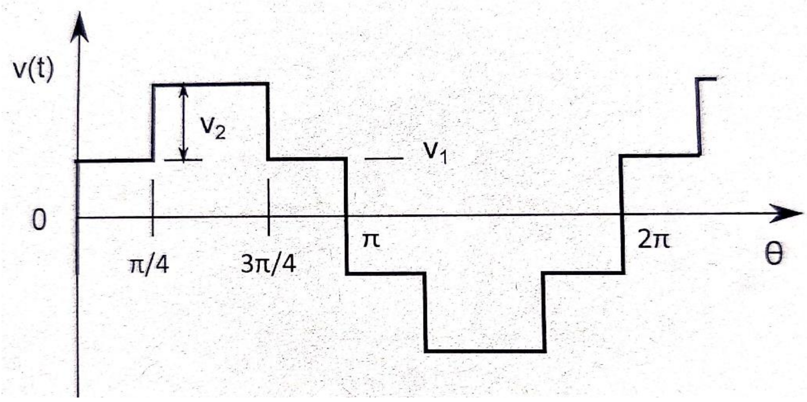
Answer all Questions. Each question carries 5 Marks

1	Realize a 4-quadrant switch using (i) Four diodes and one IGBT (ii) Four IGBTs and one diode
2	Explain with waveforms and mathematical equations, the working of single pulse width modulation technique for voltage control of a single phase inverter
3	Examine third harmonic reference injection of carrier based modulation of three-phase inverter. Derive the optimum value of magnitude of 3rd harmonic modulating signal in terms of magnitude of fundamental modulating signal.
4	Differentiate between 30° and 60° Bus Clamping PWM schemes with space vector diagram and waveforms.
5	Describe in detail operation of diode-clamped multilevel inverter

PART B

Answer any 5 Questions. Each question carries 7 Marks

6 Figure shows the output voltage waveform of an inverter. Assume suitable symmetries. It is required to eliminate the 3rd harmonic content in the waveform.



(i) Evaluate the ratio (V_1/V_2) so that the inverter output voltage is free from 3rd harmonic content.
(ii) Evaluate V_1 if the rms value of output voltage is 230 V.

	(iii) Calculate THD of the output voltage under this condition. Illustrate with proper waveforms detailed working of unipolar and bipolar modulation for three phase inverter
7	A 3-phase, 2-level inverter is operated with sinusoidal PWM (SPWM). Carrier signal has frequency, fc = 5 kHz and amplitude varies between ±10 V. Frequency of the modulating signal, fm = 50 Hz and amplitude modulation index is 0.8. Calculate the maximum and minimum width of the pole voltages (measured with respect to the DC-bus midpoint).
8	Illustrate phase leg reference for space vector modulation technique for every 60º interval in tabular form for all three phases .Also explain the MATLAB implementation of space vector modulation fed three phase VSI.
9	Sketch the trajectory of the tip of the stator flux ripple in a subcycle in sector-1, if conventional sequence (0-1-2-7) is employed and the voltage reference vector, V_{REF} = 0.4 V_{DC} and α = 15°. Also sketch the d-axis ans q-axis components of the stator flux ripple vector. Note: Stator flux ripple vector is the time integral of the error between the applied voltage vector and the reference vector in a real-time PWM inverter.
10	Calculate the conduction and switching losses in a PWM inverter with a DC bus voltage of 650 V, feeding a load at a powerfactor of 0.866 (lag). The fundamental line current is 10 A (rms) and the inverter is switched using sine-triangle PWM with a carrier frequency of 3 kHz. Assume the forward drops of the IGBT and the diode to be 3 V and 2 V, respectively. The total device switching time is 500 ns.
11	Explain the working of advanced bus clamping PWM techniques with suitable sketches.
12	With suitable sketches, explain the implementation of space vector PWM in three level VSI.

Syllabus

Module-1 (7 hrs.)

Power electronic converters for dc-dc and dc-ac power conversion:

Electronic switches; Practical realisation starting from ideal switch model- dc-dc buck and boost converters; Concept of switching voltage regulators; Voltage control in DC-DC converters- open loop and closed loop control.

Practical realisation starting from ideal switch model - H-bridge- voltage source and current source converters; Evolution of topologies for dc-ac power conversion from dc-dc converters.

Purpose of Pulse-width modulation:

Review of Fourier series-fundamental and harmonic voltages; Machine model for harmonic voltages; Undesirable effects of harmonic voltages – line current distortion- increased losses- pulsating torque in motor drives; Control of fundamental voltage; Mitigation of harmonics and their adverse effects.

Module-2 (8 hrs.)

Pulse-width modulation (PWM) at low switching frequency:

Single pulse and multiple pulse PWM; Square wave operation of voltage source inverter; PWM with a few switching angles per quarter cycle, equal voltage contours, selective harmonic elimination (SHE); THD optimized PWM; Off-line PWM.

Sinusoidal pulse width modulation (SPWM):

Average pole voltages, modulation index, voltage control of 3-phase inverters, harmonic reduction; bipolar & unipolar modulation; Pulse Width Modulation of current source inverter – 1-phase & 3-phase.

Third harmonic injection (THI); Continuous PWM; Bus-clamping or discontinuous PWM

MATLAB Simulation- Sine PWM controlled Voltage source inverter

Module-3 (8 hrs.)

Space vector PWM (SVPWM):

Space vector concept and transformation-per-phase methods from a space vector perspective- space vector based modulation; Conventional space vector PWM (CSVPWM); CSVPWM- carrier-based approach; Bus-clamping PWM (BCPWM); Advanced bus-clamping PWM (ABCPWM); triangle comparison (carrier-based) approach versus space vector approach to PWM.

Bus Clamping PWM (BCPWM)- I and II- 60° degree and 30° BCPWM; Advanced bus-clamping PWM (ABCPWM), triangle comparison (carrier-based) approach versus space vector approach to PWM; Concept of Random Pulse width modulation (RPWM), Harmonic analysis of PWM techniques.

MATLAB Simulation- VSI fed 3-phase induction motor operated with SVPWM

Module-4 (12 hrs.)

Analysis of line current ripple:

Synchronously revolving reference frame-error between reference voltage and applied voltage-integral of voltage error- evaluation of line current ripple; hybrid PWM for reduced line current ripple

Analysis of dc link current:

Relation between line-side currents and dc link current; dc link current and inverter state; rms dc current ripple over a carrier cycle; rms current rating of dc capacitors

Analysis of torque ripple:

Evaluation of harmonic torques and rms torque ripple; Hybrid PWM for reduced torque ripple (assuming 3-phase induction motor as load)

Inverter loss:

Simplifying assumptions in evaluation of inverter loss; Dependence of inverter loss on line power factor; Influence of PWM techniques on switching loss; Design of PWM for low inverter loss.

Effect of dead-time on inverter output voltage for various PWM schemes.

Overmodulation:

Per-phase and space vector approaches to overmodulation; Zones of overmodulation; Average voltages in a synchronously revolving d-q reference frame; Low-frequency harmonic distortion

Module-5 (5 hrs.)

Multilevel inverter (MLI):

Introduction to multilevel inverters; Realisation using electronic switches- diode clamp, flying capacitor and cascaded H-bridge converters;

PWM schemes for multilevel inverter:

Extensions of sine-triangle PWM to multilevel inverters- voltage space vectors- space vector based PWM; Analysis of line current ripple and torque ripple

MATLAB Simulation- Multi-level inverter operated with SVPWM.

Course Plan

No	Topic	No. of Lectures(**40** hrs)
1	**Power electronic converters for dc-dc and dc-ac power conversion**	**7**
1.1	Electronic switches, Practical realisation starting from ideal switch model- dc-dc buck and boost converters	2
1.2	Concept of switching voltage regulators, Voltage control in DC-DC converters- open loop and closed loop control.	2
1.3	Practical realisation starting from ideal switch model - H-bridge- voltage source and current source converters ; evolution of topologies for dc-ac power conversion from dc-dc converters.	1
1.4	**Purpose of Pulse-width modulation** Review of Fourier series- fundamental and harmonic voltages; machine model for harmonic voltages; undesirable effects of harmonic voltages – line current distortion- increased losses- pulsating torque in motor drives, control of fundamental voltage,; mitigation of harmonics and their adverse effects.	2
2	**Pulse-width modulation (PWM) techniques**	**8**
2.1	Pulse width modulation (PWM) at low switching frequency: Single pulse and multiple pulse PWM; Square wave operation of voltage source inverter, PWM with a few switching angles per quarter cycle, equal voltage contours, selective harmonic elimination (SHE); THD optimized PWM; off-line PWM.	3
2.2	Sinusoidal pulse width modulation (SPWM): Average pole voltages, modulation index, voltage control of 3-phase inverters, harmonic reduction; bipolar & unipolar modulation; Pulse Width Modulation of current source inverter – 1-phase & 3-phase.	3
2.3	Third harmonic injection (THI); continuous PWM; bus-clamping or discontinuous PWM	2
3	**Space vector PWM (SVPWM)**	**8**
3.1	Space vector concept and transformation, per-phase methods from a space vector perspective, space vector based modulation, conventional space vector PWM (CSVPWM), CSVPWM- carrier-based approach;	3
3.2	Bus Clamping PWM (BCPWM)- I and II- 60° degree and 30° BCPWM;	2
3.3	Advanced bus-clamping PWM (ABCPWM), triangle comparison (carrier-based) approach versus space vector approach to PWM;	2
3.4	Concept of Random Pulse width modulation (RPWM), Harmonic analysis of PWM techniques.	1
4	**Inverter losses and operation under overmodulation**	**12**
4.1	**Analysis of line current ripple** Synchronously revolving reference frame; error between reference voltage and applied voltage, integral of voltage error; evaluation of line current ripple; hybrid PWM for reduced line current ripple	2
4.2	Analysis of dc link current: Relation between line-side currents and dc link current; dc link current and inverter state; rms dc current ripple over a carrier cycle; rms current rating of dc capacitors	2
4.3	Analysis of torque ripple: Evaluation of harmonic torques and rms torque ripple, hybrid PWM for reduced torque ripple (assuming 3-phase induction motor as load)	2

4.4	Inverter loss: Simplifying assumptions in evaluation of inverter loss, dependence of inverter loss on line power factor, influence of PWM techniques on switching loss, design of PWM for low inverter loss.	3
4.5	Effect of dead-time on inverter output voltage for various PWM schemes	1
4.6	Over modulation: Per-phase and space vector approaches to over modulation, zones of over modulation, average voltages in a synchronously revolving d-q reference frame, low-frequency harmonic distortion	2
5	**Multilevel inverters**	**5**
5.1	Multilevel inverter (MLI): Introduction to multilevel inverters, realisation using electronic switches- diode clamp, flying capacitor and cascaded H-bridge converters;	2
5.2	PWM schemes for multilevel inverter: Extensions of sine-triangle PWM to multilevel inverters, voltage space vectors, space vector based PWM, analysis of line current ripple and torque ripple	3

Reference Books

1. Dr. G. Narayanan, IISc, Bangalore, NPTEL Online Video course on "Pulse width Modulation for Power Electronic Converters" 2016.
2. D Grahame Holmes, Thomas A Lipo, Pulse Width Modulation for Power Converters: Principles and Practice, IEEE Press
3. Mohan, Undeland and Robbins, "Power Electronics: Converter, Applications and Design", Wiley India, 2011.
4. B K Bose, Modern Power Electronics and AC Drives, PHI
5. Bin WU, High Power Converters and AC drives, John Wiley
6. M H Rashid (Ed), Power Electronics Handbook, Academic Press
7. Haitham Abu-Rub, Atif Iqbal, JaroslawGuzinski , "High Performance Control of AC Drives with Matlab/Simulink Models", John Wiley and Sons Inc., 2012.

222EEE024	HYBRID & ELECTRIC VEHICLES	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 3	3	0	0	3

Preamble: Nil

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	Familiarise with various sensors and 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 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 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
Second Semester M.Tech Degree (R) Examination Month & Year

222EEE024 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 drivetrains 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, $0\le t\le 10$ s

(a) Tractive force as function of time for $0\le t\le 10$ s
(b) Mean tractive power over interval $0\le t\le 10$ 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	**Introduction to Hybrid & Electric Vehicles (8 hours)** History of hybrid & electric vehicles, social and environmental importance of hybrid & electric vehicles, Impact of modern drive-trains on energy supplies, Conventional vehicles: Basics of vehicle performance, vehicle power source characterization, Transmission characteristics, mathematical models to describe vehicle performance, Drive cycles and their impact on vehicle operation
Module 2	**Hybrid Electric Drive-trains (8 hours)** Basic concepts of hybrid traction, introduction to various hybrid drive-train topologies, Power flow control in hybrid drive-train topologies, fuel efficiency analysis, Electric drive-trains: Basic concepts of electric traction, Introduction to various electric drive-train topologies, Power flow control in electric drive-train topologies
Module 3	**Electric Propulsion System (8 hours)** Introduction to electric components used in hybrid an electric vehicles, Desired features for an EV motor, Introduction to various EV motors, T-w characteristics, Configuration and control of Brushless DC Motor drives, Configuration and control of Permanent Magnet Synchronous Motor drives, Configuration and control of Induction Motor drives, Configuration and Control of Switched Reluctance Motor drives, Protection schemes for power converters
Module 4	**Energy Storage Systems (8 hours)** Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis, SoC estimation, Other advanced storage topologies - Supercapacitor based system, Fuel cell based system, Fly wheel based system, Hybridization of different energy storage devices, Introduction to Energy Management Strategies in Hybrid and Electric vehicles, classification and comparison of various strategies, Implementation issues for energy management strategies
Module 5	**Sizing of Drive System, In-vehicle Communication (8 hours)** Matching the electrical machine and IC engine, Sizing of propulsion motor, Sizing of power electronic components, Selection of energy storage technology, Case studies - Design of Hybrid Electric Vehicle, Design of Battery Electric Vehicle, Automotive Sensors and Actuators, Communication between major components, In-vehicle networks - 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 an 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 vehicles, Desired features for an EV motor	1
3.2	Introduction to various EV motors, T-w 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 - Supercapacitor 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	2
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

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
222EEE017	APPLICATION OF AI IN POWER SYSTEMS	Program Elective 3	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	Detail various ANN configurations.
CO2	Develop fuzzy logic controller for power system applications.
CO3	Apply Evolutionary algorithms in electrical engineering problems
CO4	Apply Hybrid intelligent techniques in simple optimisation problems.
CO5	Demonstrate application of swarm intelligence based AI techniques in power system.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	Continuous Assessment Tests	End Semester Examination
	1	
Remember		
Understand	20%	30%
Apply	40%	40%
Analyse	20%	30%
Evaluate	20%	
Create		

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

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

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

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

End Semester Examination Pattern:

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

SECOND SEMESTER M.TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 222EEE017

Course name: APPLICATION OF AI IN POWER SYSTEMS

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

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

1) List down the characteristics of intelligent agent.

2) Explain the structure of a feedforward ANN with two hidden layers.

3) Two fuzzy sets P and Q are defined on xɛ X as follows.

x_1	x_2	x_3	x_4	x_5	
P	0.1	0.2	0.7	0.5	0.4
Q	0.9	0.6	0.3	0.2	0.8

Find $(P \cup Q')_{0.4}$

4) If the population size in a genetic algorithm is restricted to 1, what search algorithm does it correspond to? Explain your answer.

5) With reference to Ant Colony Optimisation describe these algorithmic elements:

a. Evaporation

b. Transition Probability

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

6) Explain the application of Artificial Neural Network in Power system Load Frequency Control.

7) Explain a fuzzy based speed control of DC motor. Take field control method; explain with maximum of three linguistic variables for input variable.

8) Suppose a genetic algorithm uses chromosomes of the form x = abcdefgh with a fixed length of eight genes. Each gene can be any digit between 0 and 9. Let the fitness of individual x be calculated as: f(x) = (a + b) − (c + d) + (e + f) − (g + h) ,and let the initial population consist of four individuals with the following chromosomes:

x1 = 6 5 4 1 3 5 3 2

x2 = 8 7 1 2 6 6 0 1
x3 = 2 3 9 2 1 2 8 5
x4 = 4 1 8 5 2 0 9 4

9) Draw the flow chart of PSO. Show how the Particles Adjust their positions according to a ``Psychosocial compromise''. Discuss the useful parameters in PSO.

10) Explain the Major Characteristics of Ant Colony Search Algorithms for getting rapid solution for non-linear optimization problems.

11) Describe in detail GA-Fuzzy System Approach for Optimal Power Flow Solution

12) Explain different layers of Adaptive Neuro Fuzzy Inference System.

No.	Syllabus
1	**Introduction to Artificial Intelligence and Optimisation (8 hours)**
	Artificial Intelligence and Optimisation: **Introduction to Optimisation**- Statement of an optimization problem – Classification of optimisation problems-Nonlinear Programming-Single Variable Optimization -Multivariable Optimization with no Constraints- Necessary and Sufficient Conditions for optimality -Unimodal and Multimodal functions– Concept of Global optimum and Local optimum. **AI program**: Definition, Applications, Components; Production system. Problem Characteristics. Overview of searching techniques. Knowledge representation: Knowledge representation issues; and overview. Representing knowledge using rules; procedural versus declarative knowledge. Logic programming, forward versus backward reasoning, matching. Control knowledge.
2	**Artificial Neural Networks (9 hours)**
	Artificial Neural Network: difference between human machine and intelligence, biological neural network, artificial neuron model, Concept of Perceptron, ADALINE, Feedback in Neural Network, Neural Network Architectures: Neural Learning, supervised and unsupervised learning back propagation. Application of Neural Network in Power System- Electrical Load Forecasting Problem, Load Frequency Control Problem
3	**Fuzzy Logic (7 hours)**
	Introduction, Foundation of Fuzzy Systems, Representing Fuzzy Elements, Basic Terms and Operations, Operations on Fuzzy Sets, Fuzzy Intersection, Union, Concentration, dilation etc. Properties of Fuzzy Sets, Fuzzification, Arithmetic Operations of Fuzzy Numbers, The alpha cut method, The extension method, Linguistic Descriptions and their Analytical Forms, Fuzzy Linguistic Descriptions, Fuzzy Relation Inferences, Fuzzy Implication and Algorithms, Defuzzification Methods, Centre of Area Defuzzification, Centre of Sums Defuzzification. Applications of Fuzzy Rule Based System- Speed control of DC motor, Power System Stabilizer Using Fuzzy Logic

4	**Genetic Algorithms ,Evolutionary Programming and Hybrid Techniques (8 hours)**
	Genetic Algorithms: Procedure of Genetic Algorithms, Genetic Representations, Initialization and Selection, Genetic Operators, Mutation, Working of Genetic Algorithms, Effect of Crossover Probability on GA Performance Evolutionary Programming, The Working of Evolutionary Programming. Applications of Genetic Algorithms to simple optimization problems. **Adaptive Neuro Fuzzy Systems** : Adaptive Neuro-Fuzzy Inference Systems – ANFIS architecture, First order Sugeno fuzzy models, Tsukamoto fuzzy model.
5	**GA-Fuzzy systems and Swarm Intelligence for Power System Applications (8 Hours)**
	GA-Fuzzy systems: GA-Fuzzy System Approach for Optimal Power Flow Solution, Applications such as Transmission Pricing Model Under Deregulated Environment, Congestion Management Using GA-Fuzzy Approach. **Swarm intelligence**: Fundamental concepts of Ant Colony Optimisation- Ant Colony Optimization Procedure Probabilistic Transition Rule- Pheromone Updating- ACO algorithm for TSP, **Particle Swarm optimisation** – PSO parameters-Algorithm. Application of ACO for unit commitment Problem, Application of PSO - Planning of the Power Grid Network, Automatic Power Generation Control and Economic Dispatching etc.

Course Plan

No.	Topic	No. of Lectures
1	**Introduction to AI (8 hours)**	
1.1	Definition, Applications, Components of an AI program;	2
1.2	Production system. Problem Characteristics. Overview of searching techniques.	2
1.3	Knowledge representation: Knowledge representation issues; and overview.	1
1.4	Representing knowledge using rules; procedural versus declarative knowledge.	2
1.5	Logic programming, forward versus backward reasoning, matching. Control knowledge.	1
2	**Artificial Neural Networks (9 hours)**	
2.1	Biological Neuron, Neural Net,	2
2.2	use of neural 'nets, applications,	1
2.3	Perception, idea of single layer and multilayer neural nets,	1
2.4	back propagation, supervised and unsupervised learning.	2
2.5	Electrical Load Forecasting Problem, Load Frequency Control Problem	2
3	**Fuzzy Logic (7 hours)**	

3.1	Introduction, Foundation of Fuzzy Systems, Representing Fuzzy Elements,	1
3.2	Basic Terms and Operations, Properties of Fuzzy Sets, Fuzzification,	1
3.3	Arithmetic Operations of Fuzzy Numbers, The alpha cut method, The extension method, Linguistic Descriptions and their Analytical Forms,	1
3.4	Fuzzy Linguistic Descriptions, Fuzzy Relation Inferences, Fuzzy Implication and Algorithms,	1
3.5	Defuzzification Methods, Centre of Area Defuzzification, Centre of Sums Defuzzification.	1
3.6	Fuzzy applications in power system, Speed control of DC motor. Power System Stabilizer Using Fuzzy Logic	3
4	**Genetic Algorithms and Evolutionary Programming (8 hours)**	
4.1	Introduction, Genetic Algorithms, Procedure of Genetic Algorithms,	1
4.2	Genetic Representations, Initialization and Selection,	1
4.3	Genetic Operators, Mutation, Working of Genetic Algorithms,	1
4.4	Evolutionary Programming, The Working of Evolutionary Programming.	1
4.5	Adaptive Neuro Fuzzy Systems : Adaptive Neuro-Fuzzy Inference Systems – ANFIS architecture, First order Sugeno fuzzy models,	2
5	**Swarm intelligence and Application of AI techniques: (8 hours)**	
5.1	GA-Fuzzy System Approach for Optimal Power Flow Solution, Transmission Pricing Model Under Deregulated Environment, Congestion Management Using GA-Fuzzy Approach.	2
5.2	Swarm intelligence: Fundamental concepts of Ant Colony Optimisation- ACO algorithm for TSP, Particle Swarm optimisation – PSO parameters-Algorithm.	2
5.3	Load forecasting, load flow studies, economic load dispatch, load frequency control	2
5.4	Single area system and two area system, small signal stability (dynamic stability) reactive power control.	1
5.5	Application of ACO for unit commitment Problem, Application of PSO - Planning of the Power Grid Network, Automatic Power Generation Control and Economic Dispatching etc.	1

Text Books

1. N. P. Padhy, “Artificial Intelligence and Intelligent Systems,” OXFORD University Press, New Delhi, 2005

2. Devendra K. Chaturvedi, “Soft Computing Techniques and its Applications in Electrical Engineering,” Springer

3. S. S. Rao, Engineering optimization – Theory and practices, 4th edition, John Wiley and Sons, 2009.

4. K. Y. Lee and M. A. El-Sharkawi, "Modern Heuristic Optimisation technique –Theory and application to power system", John Wiley and Sons, 2008.

References

1. Stamations V. Kartalopoulos, "Understanding Neural Networks and Fuzzy Logic: Basic concepts and Applications," Prentice Hall India Private Limited, New Delhi,2002.

2. Kevin Warwick, Arthur Ekwue and Raj Aggarwal, "Artificial Intelligence Techniques in Power Systems," IEE Power Engineering Series, UK, 1997.

3. Abhisek Ukil, "Intelligent Systems and Signal Processing in Power Engineering," Springer Berlin Heidelberg, New York

4. Simon Haykin, "Neural Networks: A Comprehensive Foundation," 2nd Edition, Pearson Education.

5. Zimmermann, H. J., "Fuzzy Set Theory and Its Applications," 2nd Edition, Kluwer Academic Publishers.

6. El Hawaray, "Electrical Power Applications with Fuzzy systems AIEEE Press.

7. D. P. Kothari, J. S. Dhillon, "Power System Optimisation," PHI

8. M. Ganesh, "Introduction to fuzzy sets and fuzzy logic", Prentice Hall India.

9. Kelvin Waruicke, Arthur Ekwlle, Raj Agarwal, "AI Techniques in Power System," IEE London

10. S. Rajasekaran and G. A. V. Pai ,"Neural Networks, Fuzzy Logic & Genetic Algorithms, "-PHI, New Delhi, 2003.

11. P. D. Wasserman,Van Nostrand Reinhold, "Computing Theory & Practice," New York,1989.

12. Neural Network & Fuzzy System, Bart Kosko, Prentice Hall, 1992.

13. G. J. Klir and T. A. Folger, "Fuzzy sets, Uncertainty and Information," PHI, Pvt.Ltd,1994.

14. D.E.Goldberg, "Genetic Algorithms,", Addison Wesley 1999.

15. Digital Neural Network -S.Y Kung , Prentice-Hall of India

16. James A. Freeman and David M. Skapura, "Neural Networks Algorithms, Applications, and Programming Techniques", Pearson Edn.,

17. Jyh-Shing Roger Jang, Chuen-Tsai Sun, Eiji Mizutani, "Neuro-Fuzzy and Soft Computing", Prentice-Hall of India

18. Melanie Mitchell, " An Introduction to Genetic Algorithms", MIT Press- 1996.

19. Mohamed E. El-Hawary, "Modern Heuristic Optimisation technique –Theory and application to power system",IEEE Press.

20. Xin-She Yang, “Nature-Inspired Metaheuristic Algorithms”, Luniver Press 2010.

21. J. R. Koza: “ Genetic Programming: On the programming of computers by means of natural selection”, MIT Press- 1992.

PROGRAM ELECTIVE 4

222EEE019	POWER SYSTEM AUTOMATION	CATEGORY	L	T	P	CREDIT
		Program Elective 4	3	0	0	3

Preamble: Nil

Course Outcomes:

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

CO 1	Understand SCADA application in power system automation
CO 2	Analyse the functions of SCADA system components
CO 3	Apply SCADA communication functions for various applications
CO 4	Analyse substation automation using SCADA
CO 5	Investigate the role of SCADA in generation, transmission and distribution application functions

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation: 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:

Name: **Reg No:**

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

Course Code: 222EEE019

Course Name: Power System Automation

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	Mention different steps involved in SCADA system	5
	Module 2	
2	Analyse the functions of modern IED in SCADA system	5
	Module 3	
3	Mention main features of IEC 61850	5
	Module 4	
4	Discuss the need of substation automation automation in present scenario	5
	Module 5	
5	Describe real time automatic generation control in SCADA system	5
	PART B (7 x 5 = 35 Marks) Answer any five full questions. Each question carries 7 Marks	

6 a.	Analyse monitoring and controlling process in SCADA system	**4**
b.	Discuss the functional components of master station in SCADA system	**3**
7a.	Analyse the components of RTU	**4**
b.	Describe any two SCADA communication topologies	**3**
8.	Analyse the protective functions of intelligent bus failover and automatic load restoration using SCADA	**7**
9 a.	Discuss various SCADA communication requirements	**3**
b	Analyse the functions of digital substation	**4**
10	Discuss the functions of transmission operation management using EMS framework	**7**
11a.	Discuss EMS with WAMS	**4**
b.	Analyse various technical issues in substation automation	**3**
12a.	Mention any one DMS application function	**4**
b.	Discuss advantages of SCADA in power system	**3**

Syllabus

No	Topic	No. of Lectures
1	**Introduction to Automation systems** History of automation systems, Supervisory control and data acquisition systems, Components of SCADA systems, SCADA applications SCADA in power systems: SCADA basic functions, SCADA application functions in generation, Transmission and distribution functions Advantages of SCADA in power system, industrial utility application	8
2	**SCADA systems and components** Building blocks of SCADA systems, Remote terminal unit(RTU) Intelligent Electronic Devices(IED), SCADA Communication system Master station , HMI systems	8
3	**SCADA Communication System** SCADA Communication requirements, SCADA communication topologies, SCADA Data communication techniques SCADA Communication protocol architectures, IEC 61850 Guided media: optical fiber, wired and wireless methods	8
4	**Substation Automation** Conventional substations, New smart devices for substation automation, Technical issues New digital substation, New versus existing substations Substation Automation application functions: intelligent bus failover, automatic load restoration, adaptive relaying, Equipment condition monitoring, intelligent alarm processing, Real time equipment monitoring	8
5	**Generation, Transmission and Distribution Automation** SCADA in Generation operation and management: load forecasting, unit commitment, hydrothermal coordination, economic dispatch and real time automatic generation control Energy control centers, EMS software application Transmission operation and management real time: State estimation, contingency analysis, islanding of power systems	8

	EMS with wide area monitoring systems(WAMS) Distribution Automation: customer automation, feeder automation, substation automation, subsystems in a distribution control centre, DMS application functions	

Course Plan

No	Topic	No. of Lectures
1	**Introduction to Automation systems**	
1.1	History of automation systems, Supervisory control and data acquisition systems, Components of SCADA systems, SCADA applications	3
1.2	SCADA in power systems: SCADA basic functions, SCADA application functions in generation, Transmission and distribution functions	3
1.3	Advantages of SCADA in power system, industrial utility application	2
2	**SCADA systems and components**	
2.1	Building blocks of SCADA systems, Remote terminal unit(RTU)	4
2.2	Intelligent Electronic Devices(IED), SCADA Communication systems	2
2.3	Master station , HMI systems	2
3	**SCADA Communication System**	
3.1	SCADA Communication requirements, SCADA communication topologies, SCADA Data communication techniques	3
3.2	SCADA Communication protocol architectures, IEC 61850	3
3.3	Guided media: optical fiber, wired and wireless methods	2
4	**Substation Automation**	
4.1	Conventional substations, New smart devices for substation automation, Technical issues	2
4.2	New digital substation, New versus existing substations	2

4.3	Substation Automation application functions: intelligent bus failover, automatic load restoration, adaptive relaying, Equipment condition monitoring, intelligent alarm processing, Real time equipment monitoring	4
5	**Generation, Transmission and Distribution Automation**	
5.1	SCADA in Generation operation and management: load forecasting, unit commitment, hydrothermal coordination, economic dispatch and real time automatic generation control	2
5.2	Energy control centers, EMS software application Transmission operation and management real time: State estimation, contingency analysis, islanding of power systems EMS with wide area monitoring systems(WAMS)	3
5.3	Distribution Automation: customer automation, feeder automation, substation automation, subsystems in a distribution control centre, DMS application functions	3

Reference Books

1. Mini S Thomas, John D Mc Donald , Power System SCADA and Smart Grids, CRC Press, Taylor and Francis Group
2. Stuart A Boyer, SCADA- Supervisory control and Data Acquisition System, ISA Fourth edition
3. Praveen Arora, SCADA and Power system, nortion Press, **ISBN**- 979-8885466912

SYLLABUS

222EEE016	**NONLINEAR CONTROL SYSTEMS**	**CATEGORY**	**L**	**T**	**P**	**CREDIT**
		Program Elective 4	3	0	0	3

Preamble: This course is intended to give a fundamental understanding of Nonlinear Control Systems and to equip the students to pursue research and development in the field of nonlinear control design.

Course Outcomes:

After the completion of the course the student will be able

CO 1	To be able to develop mathematical models of physical systems, to find the equilibrium sets, classify their types and to comprehend nonlinear phenomenon.
CO 2	To study the notion of Lipschitz continuity and its usefulness in establishing the existence and uniqueness of solution of a differential equation.
CO 3	To understand the various notions of stability and to be able to apply Lyapunov based analysis in establishing them.
CO 4	To be able to analyze the nonlinear systems for their absolute stability.
CO 5	To design nonlinear control techniques using linearization and recursive design techniques.

The departments conducting the M.Tech programme shall define their own PSOs, if required, and assessment shall also be done for the same.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

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

Continuous Internal Evaluation Pattern:

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

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

Test paper, 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus.

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

QP CODE:	PAGES: 2
Reg.No:______________	Name:

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M. TECH DEGREE EXAMINATION

MONTH & YEAR

Course Code**: 222EEE016**

Course Name: **NONLINEAR CONTROL SYSTEMS**

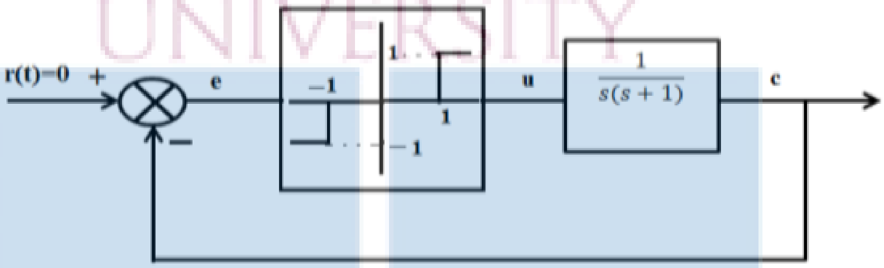
Max. Marks: 60 **Duration: 2.5 Hours**

PART A

Answer all questions

Each question carries 5 marks

1		What are singular points? Classify singular points based on Eigen values with necessary equations and phase trajectories.	5
2		State and prove the theorem on continuity of solutions in terms of initial states and parameters.	5
3		Check the stability of the following system using Lyapunov Stability analysis $\dot{x_1} = x_1(k^2 - {x_1}^2 - {x_2}^2) + x_2(k^2 + {x_1}^2 + {x_2}^2)$ $\dot{x_2} = -x_1(k^2 + {x_1}^2 + {x_2}^2) + x_2(k^2 - {x_1}^2 - {x_2}^2)$ When a) k=0 b) $k \neq 0$	5
4		Explain loop transformation applied to circle criterion.	5
5		Write notes on Integral control via linearization.	5

		PART B **Answer any 5 full questions**	
6		For the system shown in Fig.1 with relay and dead zone as nonlinear element, draw the phase trajectory originating from the initial condition (3,0) using Isocline Method  Fig.1	7
7	a	Define Lipschitz function with suitable examples.	3
	b	Obtain the Lipschitz constant of the function $$f(x) = \begin{bmatrix} x_2 \\ -sat(x_1 + x_2) \end{bmatrix}$$	4
8		State LaSalle's invariance principle. Show that the origin is locally asymptotically stable for the following system using LaSalle's principle. $\dot{x}_1 = x_2$ $\dot{x}_2 = -3x_2 - x_1^3$	7

9		Find the sector [α, β] for which the given scalar transfer function is absolutely stable using Circle Criterion $$G(s) = \frac{s+2}{(s+1)^3}$$ $\dot{x}_1 = x_2 +$ $\dot{x}_2 = - x_1 -$	7
10		Using backstepping, design a state feedback control law to globally stabilize the following system $$\dot{x}_1 = ax_1^{\,2} - x_1^{\,3} + x_2$$ $$\dot{x}_2 = u$$	7
11		Consider the system $$\dot{x}_1 = e^{x_2} - 1$$ $$\dot{x}_2 = ax_1^2 + u$$ Is this system feedback linearizable? If yes, find a feedback control law that linearizes the state equation.	7
12		Show that the following is input – state linearizable and obtain the co-ordinate transformation for the same. $$\dot{x}_1 = \exp(x_2)\,u$$ $$\dot{x}_2 = x_1 + x_2^{\,2} + \exp(x_2)\,u$$ $$\dot{x}_3 = x_1 - x_2$$	7

Syllabus

No	Topic
1	**Introduction and background (7 hours)** Non-linear system characteristics and mathematical modelling of non-linear systems. Classification of equilibrium points, Linearization about equilibria of second order nonlinear systems. Bifurcations-different types, Phase plane analysis of nonlinear systems
2	**Nonlinear characteristics (8 hours)** Closed orbits of planar dynamical systems Open sets, closed sets, connected sets, Invariant set theorem, Bendixson's theorem and Poincare-Bendixson criteria Existence and uniqueness of solutions to nonlinear differential equations with proof, Continuous dependence on initial conditions and parameters
3	**Stability Analysis (7 hours)** Lyapunov stability theorems- local stability - local linearization and stability in the small- region of attraction The direct method of Lyapunov-Construction of Lyapunov functions, La Salles's invariance principle
4	**Analysis of feedback systems (9 hours)** Passivity, L stability and loop transformations PR Lemma, KYP Lemma, Absolute stability Circle Criterion - Popov Criterion
5	**Nonlinear control systems design (9 hours)** Basics of Differential Geometry-Controllability of nonlinear systems Feedback linearization_Input state linearization method-Input-output linearization method, Zero Dynamics for SISO systems Stabilization - regulation via integral control- gain scheduling Backstepping

Course Plan

No	Topic	No. of Lectures
1	**Introduction and background (7 hours)**	
1.1	Non-linear system characteristics and mathematical modelling of non-linear systems.	2
1.2	Classification of equilibrium points, Linearization about equilibria of second order nonlinear systems.	2
1.3	Bifurcations-different types, Phase plane analysis of nonlinear systems.	3
2	**Nonlinear characteristics (8 hours)**	
2.1	Closed orbits of planar dynamical systems	1
2.2	Open sets, closed sets, connected sets, Invariant set theorem, Bendixson's theorem and Poincare-Bendixson criteria	3
2.3	Existence and uniqueness of solutions to nonlinear differential equations with proof, Continuous dependence on initial conditions and parameters	4
3	**Stability Analysis (7 hours)**	
3.1	Lyapunov stability theorems- local stability - local linearization and stability in the small- region of attraction	2
3.2	The direct method of Lyapunov	2
3.3	Construction of Lyapunov functions, La Salles's invariance principle.	3
4	**Analysis of feedback systems (9 hours)**	
4.1	Passivity, L stability and loop transformations	3
4.2	PR Lemma, KYP Lemma, Absolute stability	2
4.3	Circle Criterion	2
4.4	Popov Criterion	2
5	**Nonlinear control systems design (9 hours)**	
5.1	Basics of Differential Geometry-Controllability of nonlinear systems	2
5.2	Feedback linearization_Input state linearization method-Input-output linearization method, Zero Dynamics for SISO systems	3
5.3	Stabilization - regulation via integral control- gain scheduling	2
5.4	Backstepping	2

Text Book:

1. Khalil H. K, Nonlinear Systems, 3/e, Pearson
2. Gibson J.E. Nonlinear Automatic Control, Mc Graw Hill.
3. Slotine J. E and Weiping Li, Applied Nonlinear Control, Prentice-Hall,

References:

1. Alberto Isidori, "Nonlinear Control Systems: An Introduction", Springer-Verlag, 1985.
2. M. Vidyasagar, "Nonlinear Systems Analysis", Prentice-Hall, India, 1991.
3. Shankar Sastry, "Nonlinear System Analysis, Stability and Control", Springer, 1999.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE021	DISTRIBUTION SYSTEM ANALYSIS	Elective 4	3	0	0	3

Preamble:

Analysis of distribution systems is gaining more importance due to the integration of distributed generators. The aim of this course is to enrich the students with the analysis and protection aspects of distribution systems to enable them to carry out research in the area.

Course Outcomes:

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

CO 1	Develop mathematical models of distributions systems
CO 2	Analyse distribution system load flow and short circuit
CO 3	Investigate reconfiguration and restoration in distribution systems
CO 4	Operate distribution systems in an optimally by proper volt/var control schemes
CO 5	Develop protection schemes for distribution systems

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's 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:

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.
Note: SCILAB/MATLAB based simulation work can also be considered for course based task.

End Semester Examination Pattern:

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

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

Model Question paper

D

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 20XX

ELECTRICAL AND ELECTRONICS ENGINEERING

Streams: POWER SYSTEMS

222EEE021 DISTRIBUTION SYSTEM ANALYSIS

Max. Marks: 60 Duration: 2.5 Hours

Part A

Answer ALL Questions

1	Discuss the applications of synchrophasors in distribution systems.	(5)
2	Explain the nature of fault currents in distribution system under short circuit.	(5)
3	Distinguish between FLISR distributed intelligence and FLISR local intelligence.	(5)
4	Enumerate the methods to improve voltage regulation of distribution systems.	(5)
5	Explain recloser-sectionalizer coordination in a distribution system.	(5)

(5x5=25 marks)

Part B

Answer any FIVE full Questions

6	Derive exact line segment model of a distribution system	(7)
7	Explain the algorithm to conduct load flow in a radial distribution system.	(7)
8	Discuss the objectives of network reconfiguration with the help of examples.	(7)
9	Develop an optimal strategy for the location and sizing of distribution systems.	(7)
10	Compare the protection philosophy in distribution systems with and without distributed generators.	(7)
11	a) Enumerate the functionalities of distribution management systems.	(3)
	b) Discuss the fuse setting criteria in a distribution system.	(4)
12	a) Explain how the introduction of capacitors in a distribution system causes reduction in losses.	(3)
	b) Write notes on the synchronisation of distributed generators to the distribution systems	(4)

Syllabus

No	Topic	No. of Lectures
1	Introduction to Distribution systems - Distribution automation functions - Distribution System Line Models	8
2	Load flow in distribution systems, Short circuit calculation, Reliability of distribution systems	8
3	Reconfiguration and restoration of distribution systems	8
4	Definition of voltage regulation - Voltage regulators - Capacitor application in distribution systems - Capacitor sizing and location	8
5	Fundamentals of overcurrent protection - Protection coordination principles - Protection equipment installed along the feeders- Protection considerations when distributed generation - Short circuit levels	8

Course Plan

No	Topic	No. of Lectures
1	**Introduction to Distribution Systems**	
1.1	Distribution system – radial and ring main systems, Distribution Substations – Numerical Examples	2
1.2	Distribution automation functions: Electrical system automation - EMS functional scope - DMS functional scope - Functionality of DMS - Geographic information system - Communication options - Supervisory control and data acquisition - Synchrophasors and its application in power systems	3
1.3	Distribution System Line Models: Exact Line Segment Model - The Modified Line Model - The Three-Wire line	3
2	**Distribution System Analysis**	
2.1	Load flow - Formulation of the load flow problem, Newton–Raphson method - Type of buses - Application of the Newton–Raphson method to solve load flows- Decoupling method	2
2.2	Radial load flow concepts: Theoretical background - Distribution network models - Nodes and branches identification - Algorithm to develop radial load flow – Radial distribution load flow with distributed generators.	2
2.3	Short circuit calculation Nature of short circuit currents - Calculation of fault duty values - Fault calculation for symmetrical faults - Symmetrical components - Importance and construction of sequence networks - Calculation of asymmetrical faults using symmetrical components - Equivalent impedances for a power system - Supplying the current and voltage signals to protection systems	3
2.4	Reliability of distribution systems: Network modelling -Network reduction	1

3	**Reconfiguration and restoration of distribution systems**	
3.1	Optimal topology - Location of switches controlled remotely - Feeder reconfiguration for improving operating conditions	2
3.2	Feeder reconfiguration for service restoration: Fault location, isolation, and service restoration (FLISR), Manual restoration vs. FLISR	3
3.3	Restrictions on restoration, FLISR central intelligence, FLISR distributed intelligence - FLISR local intelligence	3
4	**Volt/VAR control**	
4.1	Definition of voltage regulation - Options to improve voltage regulation - Voltage regulators	2
4.2	Capacitor application in distribution systems: Feeder model - Capacitor location and sizing, Reduction in power losses with one capacitor bank, Reduction in power losses with two capacitor banks, Loss reductions with three capacitor banks, Consideration of several capacitor banks,	3
4.3	Capacitor sizing and location using software, Modeling of distribution feeders including VVC equipment - Volt/VAR control considering SCADA - Requirements for Volt/VAR control - Integrated Volt/VAR control	3
5	**Modern protection of distribution systems**	
5.1	Fundamentals of overcurrent protection - Protection coordination principles - Criteria for setting instantaneous units - Setting time-delay relays - Setting overcurrent relays using software techniques - Coordination across Dy transformers	2
5.2	Protection equipment installed along the feeders - Reclosers - Sectionalizers – Fuses - Setting criteria - Fuse-fuse coordination - Recloser-fuse coordination - Recloser-sectionalizer coordination - Recloser-sectionalizer-fuse coordination - Recloser-recloser coordination - Recloser-relay coordination	3
5.3	Protection considerations when distributed generation is available	1
5.4	Short circuit levels - Synchronization - Overcurrent protection - Adaptive protection	2

Reference Books

1. Juan M. Gers, "Distribution System Analysis and Automation," IET, 2014.

2. William H. Kersting, "Distribution System Modeling and Analysis", CRC Press, 2017.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222EEE026	ENERGY STORAGE SYSTEMS	Program Elective-4	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:

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

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

Test paper, 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

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

Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can 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 ℃ 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. Potential energy: Pumped hydro storage. Compressed gas system: Compressed air energy storage.	1
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 systems.	2
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

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

INTERDISCIPLINARY ELECTIVE

222EEE070	Energy Efficiency in Electrical Engineering	CATEGORY	L	T	P	CREDIT
		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:

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

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

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

End Semester Examination Pattern:

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

Model Question paper

QP CODE: **PAGES: 2**

Reg No:_____________ **Name:_______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code:

Course name: Energy Efficiency in Electrical Engineering

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

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

1) State the meaning and need of Energy Conservation.

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

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

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

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

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

6) Explain the impact of energy usage on climate.

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

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

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

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

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

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

12) Explain different energy efficient lighting control with features.

Syllabus

Module 1: Energy Scenario:

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

Module 2: Energy Efficiency in Electrical Supply System and Motors

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

Module 3: Energy Efficiency in Electrical Utilities

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

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

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

Module 5 :Energy Efficient Technologies in Electrical Systems

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

Course Plan

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

Reference Books

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

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

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

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

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

Important Links:

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

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

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

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

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

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

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

Preamble:

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

Course Outcomes:

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

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

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	**CIE**	**ESE**	**ESE Duration**

100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing Review Article based on peer reviewed Original publications (Minimum 10 publications shall be referred)	: 15 marks
Course based task/Seminar/Data Collection and interpretation	: 15 marks
Test paper, 1 nos	: 10 marks

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question. Students should answer all questions. Part B will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question paper

APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M.TECH DEGREE EXAMINATION

MONTH &YEAR

Course code: 222EEE071

Course Name: Electric charging Systems for Electric Vehicles

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

PART A

(Answer all questions. Each question carries 5 marks)

1. What is inverted mode of operation of the converter? Explain.
2. What is a two quadrant chopper? Explain.

3. Explain about the battery management systems used in EV.
4. Draw and explain the configuration of a level-1 charger.
5. Explain the CHAdeMo charging protocol for EV.

PART –B

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

6. Draw the circuit of 3 phase fully controlled rectifier with RLE load and explain the working for α=600 with necessary waveforms. Derive the expression for average output voltage.
7. A boost converter has an input voltage of Vd=10V and an average output voltage of 20V and average load current of I0=0.5A.The switching frequency is 25kHz and and L=200µH and C=220µF.Determine (a) duty ratio (b) ripple current of the inductor (c) peak current of inductor and (d) ripple voltage of capacitor.
8. Draw the circuit of 3 phase fully controlled rectifier with RL load and explain the working for α=60 degree with necessary waveforms. Derive the expression for average output voltage.
9. Explain the working of a Buck-Boost regulator, showing relevant waveforms and derive the expression for its output voltage.
10. Explain about Fuel cell based energy storage systems.
11. Explain the operation of level-3 battery charger with a neat circuit diagram.
12. Describe the various charging standards used for electric vehicles.

Syllabus

Module 1- AC-DC converters

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

Module 2- DC-DC converters

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

Module 3- Energy storage

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

Module 4- Charging infrastructure

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

Module 5- Charging Standards

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

COURSE PLAN

No	Topic	No. of Lectures
1	**AC-DC converters**	**8**
1.1	Controlled Rectifiers (Single Phase) – Half-wave controlled rectifier with R load– 1-phase fully controlled bridge rectifier with R, RL and RLE loads (continuous conduction only) –	2
1.2	Controlled Rectifiers (Single Phase) Output voltage equation – Controlled Rectifiers, Simple numeric problems	2
1.3	3-phase half-wave controlled rectifier with R load – 3-phase fully controlled converter with RLE load (continuous conduction, ripple free)	2
1.4	Controlled Rectifiers (Three Phase) Output voltage equation- Waveforms for various triggering angles (analysis not required). Simple numeric problems	2
2	**DC-DC converters**	**7**
2.1	Step down and Step up choppers – Single-quadrant, Two-quadrant and Four quadrant chopper	2
2.2	Pulse width modulation & current limit control in dc-dc converters.	1
2.3	Switching regulators – Buck, Boost & Buck-boost	2

2.4	Operations with continuous conduction mode – Waveforms – Design (switch selection, filter inductance and capacitance).	2
3	**Energy storage**	**9**
3.1	Introduction to energy storage requirements in Electric Vehicles	1
3.2	Units of Battery Energy Storage - Capacity rate-	1
3.3	Battery based energy storage systems, Types of battery-	1
3.4	Lifetime and Sizing Considerations	2
3.5	Battery Charging, Protection, and Management Systems	2
3.6	Fuel Cell based energy storage systems- Super capacitors-	1
3.7	Hybridization of different energy storage devices	1
4	**Charging infrastructure**	**8**
4.1	On-board chargers	1
4.2	Electric Vehicle Supply Equipment (EVSE) - Grid to EVSE to On-board chargers to battery pack.	1
4.3	Power flow block schematic diagrams	2
4.4	Types of charging stations - AC Level 1 & 2	1
4.5	Types of charging stations DC - Level 3,	1
4.6	Wireless charging.	1
4.7	Plug-in Hybrid EV, V2G concept	1
5	**Charging Standards**	**8**
5.1	SAE J1772, VDE-AR-E 2623-2-2, JEVS G105-1993,	2
5.2	Types of Connectors - CHAdeMo, CCS Type1 and 2,	1
5.3	GB/T - pin diagrams and differences,	1
5.4	IEC 61851 - Electric vehicle conductive charging modes	1
5.5	IEC 61980- Electric vehicle wireless power transfer systems,	1
5.6	IEC 62196 -AC Couplers Configuration, Combo AC DC Couplers	1
5.7	IS-17017 standards for EV charging.	1

Text books:

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

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

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

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

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

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

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

Test paper shall include minimum 80% of the syllabus.

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

Model Question paper

QP Code:
Name:
Reg No:

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

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

PART A (5 x 5 = 25 Marks)

Answer all Questions. Each question carries 5 Marks

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

Module 5

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

PART B (7 x 5 = 35 Marks)

Answer any five full questions. Each question carries 7 Marks

6 a. Write the applications for the following solar radiation–measuring instruments: 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, Direct PV-battery connection, Charge controller	2
5		
5.1	Grid connection principle, PV to grid topologies, Complete 3ph grid connection, 1ph d-q controlled grid connection, SVPWM,	2
5.2	Life cycle costing, Growth models, Annual payment and present worth factor	2
5.3	LCC with examples- Life Cycle Cost Analysis- Case Study based on Difference in Power Consumption Bill	2
5.4	Payback Period Calculation, Comparison of PV and Conventional Electricity Costs	1

Text Books

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

References

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

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

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

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

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

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

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

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

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

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	

222LEE001	POWER SYSTEM LAB II	CATEGORY	L	T	P	CREDIT
		Laboratory	0	0	3	2

Preamble: The purpose of this lab is to equip the students to solve and analyse various power system problems using dedicated or general simulation packages and examine with hardware solutions.

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

CO 1	Familiarize various application software packages and soft computing techniques to solve and analyse power system problems.
CO 2	Asses the different state estimation techniques
CO 3	Analyse the power system under fault conditions
CO 4	Understand the integration of renewable resources

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

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%

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

List of Experiments

Part A: POWER SYSTEM SIMULATION EXPERIMENTS

1. Power Factor Compensation and Voltage Regulation using a three phase FACTS controller
2. Simulation of HVDC systems
3. Relay coordination

4. State estimation of power system using DC load flow based WLS-SE
5. State estimation of power system using NR WLS-SE
6. Modelling and analysis of automatic load frequency control of multi-area power systems
7. Security constrained OPF using soft computing technique and simulate using application software
8. Simulation of solar PV with MPPT
9. Modelling and simulation of DFIG based wind power system
10. Short term load forecasting using ANN

Part B: POWER SYSTEM COMPONENT TESTING (Hardware experiments)

11. Familiarization of Real Time Simulator - Modelling, Control and Data Acquisition
12. Performance analysis of various PV panels in different geographic locations and at different
    seasons/time
13. Enhancing the power transfer capability of a transmission line using a series compensator
14. String efficiency of insulators
15. Evaluate the power quality under various linear and non-linear loads.

Note: *For the execution of Simulation experiments, use ETAP/PSCAD/POWER WORLD/ Any dedicated simulation package/ MATLAB*

Out of the above, a minimum of ten experiments are to be conducted. In addition to the above, the department can offer a few newly developed experiments

Reference Books

1. Power System Analysis, John J. Grainger and William D Stevenson Jr.: McGraw Hill, 2017, ISE
2. Power System Generation, Operation and Control, Allen J. Wood, Bruce Wollenberg and Gerald B. Sheble, John Wiley and Sons, 2013, 3rd Edition
3. Kothari D. P. and I. J. Nagrath, Modern Power System Analysis, 2/e, TMH, 2009 3. M. S. Naidu, V. Kamaraju, High Voltage Engineering, Tata McGraw-Hill Education, 2004
4. Renewable and Efficient Electric Power Systems, G. Masters, IEEE- John Wiley and Sons Ltd. Publishers, 2013, 2nd Edition.
5. Wadhwa C. L., Electrical Power Systems, 3/e, New Age International, 2009.