SEMESTER II

Discipline: ELECTRICAL & ELECTRONICS

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

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

Preamble:

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

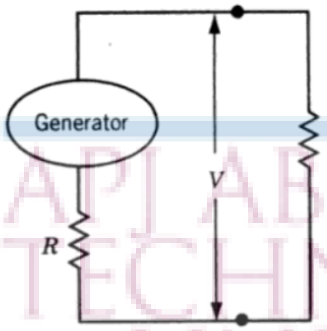
Max. Marks: 60 **Duration: 2.5 Hours**

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

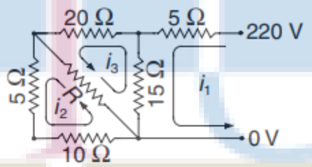


5 In which context we can use optimization methods like genetic algorithms and simulated annealing?

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 $R = 10\ \Omega$



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 $h \approx 2\ h_{max}$.

<table>
<tr><td>9</td><td>Faraday's law characterizes the voltage drop across an inductor as $\boldsymbol{V_L = L\frac{di}{dt}}$, where $\boldsymbol{V_L}$ is the voltage drop (V), $\boldsymbol{L}$ is the inductance (in henrys (H)), $\boldsymbol{i}$ is the current (in Amps), and $\boldsymbol{t}$ is the time (in secs). Determine the voltage drop as a function of time from the following data for an inductance of *4 H*.
<table>
<tr><td>Time, t (secs)</td><td>0</td><td>0.1</td><td>0.2</td><td>0.3</td><td>0.5</td><td>0.7</td></tr>
<tr><td>Current, i (Amps)</td><td>0</td><td>0.1</td><td>0.32</td><td>0.56</td><td>0.84</td><td>2.0</td></tr>
</table></td></tr>
<tr><td>10</td><td>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.</td></tr>
<tr><td>11</td><td>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.</td></tr>
<tr><td>12</td><td>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.</td></tr>
</table>

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

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

Preamble:

This course focuses on vector control schemes which offer good dynamic performance when compared to classical scalar control schemes. Dynamic modelling and performance analysis of advanced drive schemes for induction machines, PMSM and BLDC motors are also covered in the syllabus. The concepts studied in the course will also be useful in other related applications such as EV battery chargers, FACTS, and custom power devices. After successful completion of the course, the students will be able to apply the control schemes for the control of Induction motors, permanent magnet synchronous motors, BLDC motors, front end rectifiers etc. Basic courses on Electrical machines and Power Electronics are desirable as prerequisites for the course

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

CO 1	Develop dynamic modelling of different types of Electrical Machines
CO 2	Analyse speed control schemes with good dynamic performance
CO 3	Select suitable power converters
CO 4	Compare the performance of different speed control schemes
CO 5	Design suitable drive schemes

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

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

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

Syllabus

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

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

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

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

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

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

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

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

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

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

Syllabus and Course Plan

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

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

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

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

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

References

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

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

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

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

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

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

Model Question Paper

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

PART A				
Answer all Questions. Each question carries 5 Marks				
Sl. No	Question	Marks	CO	BL
1	Show that power invariance is maintained in the transformation of three phase to two phase voltages and currents	5	1	2
2	Derive the time constants associated with the flux producing channel in an indirect vectorcontrolled induction motor drive and compare with that of separately excited dc motor	5	2	3
3	Explain the operation of any suitable drive scheme for BLDC motor during forward motoring and regenerative braking	5	5	3
4	Explain parameter sensitivity issues and the effects of parameter sensitivity in stator flux oriented vector control scheme	5	3	1
5	What do you mean by airgap line, recoil line, and magnet stabilization? Explain why the maximum energy product point is not a preferred operating point. Compare NdFeB, SmCo, Alnico and ceramic magnets for use in permanent magnet machines in terms of the above terms	5	4	1
PART –B				
(Answer any five questions, each question carries 7 marks)				
6	(a) What do you mean by sinusoidal winding distribution? A sinusoidal distributed winding carries a three-phase current expressed as ia=10cos(314t), ib=10cos(314t-120˚) and ic=10cos(314t-240˚). Determine	3	1	4

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

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

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

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

Course Outcomes:

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

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

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

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

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: 40 marks

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

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

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

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

MODULE	COURSE CONTENT (40 hrs)	HRS
I	**Power transmission problems and emergence of facts solutions:** Fundamentals of ac power transmission, transmission problems, power flow, controllable parameters. Power quality – basic concept. Voltage regulation and reactive power flow control- Needs, emergence of FACTS- Types of FACTS controllers-Advantages and disadvantages - shunt compensation - Series compensation -Phase angle control –basic relationships	8
II	**Shunt compensators:** Objectives of shunt compensation-shunt SVC-TCR – TSC – Effect of initial charge - combined TCR and TSC configurations – characteristics - Analysis -Elimination of harmonics – Control schemes - Static synchronous compensator (STATCOM) configuration and control, comparison between SVC and STATCOM - Applications- case studies	9
III	**Series compensators**: Static series compensation –Objectives- GCSC – TSSC – TCSC characteristics – Basic Control Schemes - Sub synchronous characteristics- Basic NGH SSR Damper - Static Synchronous Series Compensator (SSSC): Principle of operation – Analysis and characteristics - control scheme.	8
IV	**Unified power flow controller (UPFC):** Principles of operation and characteristics, independent active and reactive power flow control, comparison of UPFC to the controlled series compensators, control structure and dynamic performance. Interline Power Flow Controller (IPFC) – Basic operating Principles and Characteristics and control schemes.	7

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

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

Course Plan

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

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

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

Model Question paper

APJ Abdul Kalam Technological University

222EEE100– FACTS and Custom Power Devices

Time : 3 hrs. Max.Marks:60

PART A (5X5=25 marks)

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

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

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

4) Explain the basic concept of UPFC control scheme.

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

PART B

Answer any 5 questions

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

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

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

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

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

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

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

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

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

Course Outcomes:

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

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

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: 40 marks

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

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

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

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

Model Question paper

QP CODE: **PAGES:**

Reg No:______________ **Name:**_______________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 222EE001

Course name: SOLAR AND WIND POWER CONVERSION SYSTEMS

Max Marks: 60 Duration: 2.5 Hours

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

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

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

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

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

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

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

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

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

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

and possible remedies

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

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

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

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

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

Syllabus

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

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

Course Plan

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

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

References:

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

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

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

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

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

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

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

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

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

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	40%

Analyse	30%
Evaluate	20%
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Mark distribution

Total Marks	CIE	ESE	ESE Duration
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Continuous Internal Evaluation Pattern:

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

End Semester Examination Pattern:

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

Model Question paper

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

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

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

Syllabus

Module I (7 hrs)

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

Module II (7 hrs)

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

Module III (9 hours)

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

Module-IV (9 hrs)

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

Module-V (8 hrs)

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

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

Syllabus and Course Plan

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

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

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

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

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

References:

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

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

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12. A Keyhani, M Marwali, "Smart power grids", Springer, 2011
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14. IEEE Std C37.112-2018 - IEEE Standard for Inverse-Time Characteristics Equations for Overcurrent Relays, DOI: 10.1109/IEEESTD.2019.8635630
15. IEEE Std 142-2007 - IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems, DOI: 10.1109/IEEESTD.2007.4396963

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

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

Preamble:

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

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

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

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	**End Semester Examination**
Apply	40%

Analyse	30%
Evaluate	20%
Create	10%

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

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

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

End Semester Examination: 60 marks

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

Syllabus

Module 1 (8 hrs)

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

Module 2 (7 hrs)

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

Module 3 (9 hrs)

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

Module 4 (8 hrs)

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

Module 5 (8 hrs)

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

Syllabus and Course Plan

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

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

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

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

References

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

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

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

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

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

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

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

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

SLOT: C

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Branch: **Electrical and Electronics**

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

Course Code: **CODE 222EEE003**

Name: **MULTILEVEL INVERTERS AND MODULATION TECHNIQUES**

Max. Marks: 60 Duration : 2.5 hours

Part A

(Answer all questions)

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

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

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

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

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

Part B

(Answer any five questions)

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

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

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

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

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

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

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

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

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

Course Outcomes:

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

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

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	
Analyse	
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

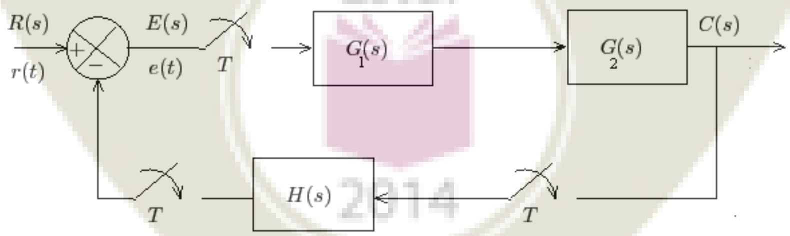
Continuous Internal Evaluation: 40 marks

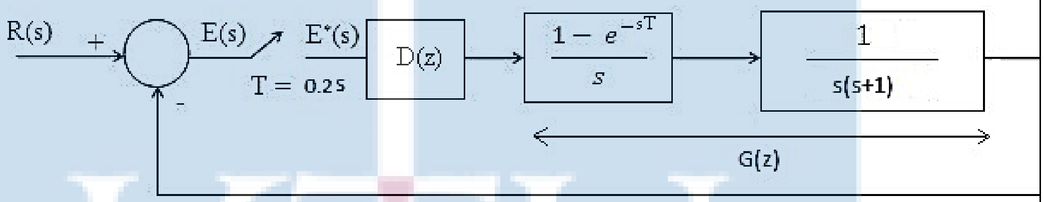
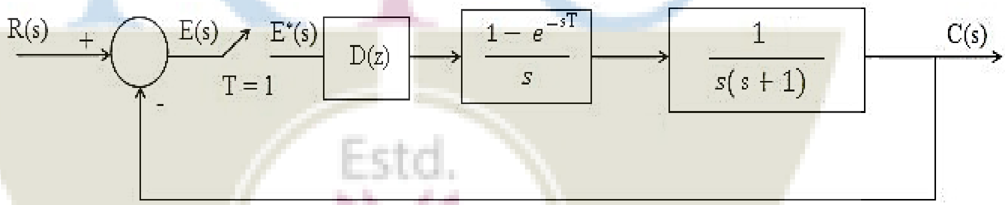
Preparing a review article based on peer reviewed
Original publications (minimum 10 publications shall be referred) : 15 marks
Course based task/Seminar/Data collection and interpretation : 15 marks

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

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

Model Question paper

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

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

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

SYLLABUS

MODULE I (9 hours)

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

MODULE II (8 hours)

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

MODULE III (8 hours)

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

MODULE IV (9 hours)

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

MODULE IV (6 hours)

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

COURSE PLAN

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

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

Reference Books

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

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

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

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

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

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

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

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

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

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

Course Outcomes:

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

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

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

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

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

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

End Semester Examination Pattern:

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

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

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

Model Question paper

QP CODE: **PAGES: 1**

Reg No: _______________ **Name:** _________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 222EE007

Course name: POWER SYSTEM DYNAMICS AND STABILITY

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

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

1. Draw and explain power system control hierarchy?

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

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

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

5. Describe the principal factors contributing to voltage collapse

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

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

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

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

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

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

11. Explain static analysis used for voltage stability

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

Syllabus

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

Course Plan

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

5.6	Sensitivity analysis, voltage collapse and its prevention	2

References

1. Kundur P, "Power System Stability and Control", TMH

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

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

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

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

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

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

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

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

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

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

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Evaluate	25 %
Create	25%

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

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

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

End Semester Examination: 60 marks

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

Syllabus

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

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

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

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

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

Course Plan

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

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

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

Reference Books

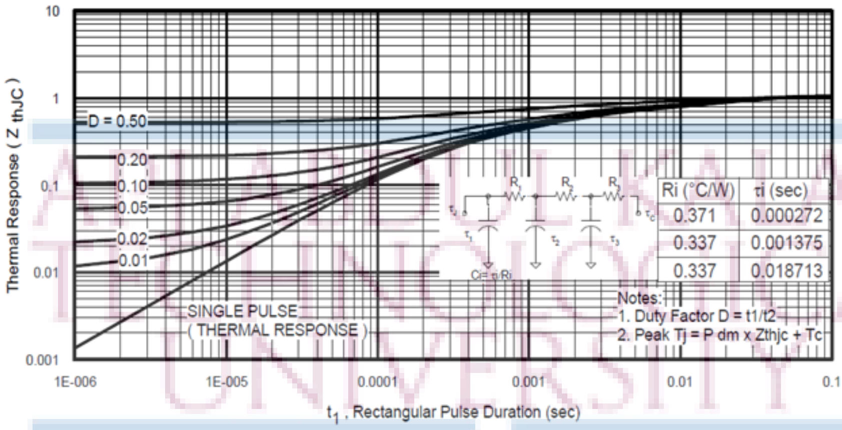
1. Ned Mohan, Tore M. Undeland and William P.Riobbins, " Power Electronics—Converters, Applications and Design" Third Edition, John Wiley and Sons. Inc2014
2. L. Umanand, "Power Electronics-Essentials and Applications", Wiley, 2014
3. Daniel W. Hart, "Power Electronics", Tata McGraw Hill, 2011
4. H.W.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

Model Question paper

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

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

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

				
	(b) A student used IRFZ44 MOSFET without any heatsink in a switching regulator application where the switching loss is 1.5W and conduction loss is 0.85W. The thermal resistance RΘj-a of the MOSFET is 62 □C/W. What is the typical temperature at the junction at this operating condition? Is the design acceptable? Give your comments.	4	3	3
9	(a) Select suitable airgap length and number of turns for the transformer in a forward converter. Use EE42/21/20 ferrite core. It is given that battery Voltage=12V, Output voltage=200V, Output power=20W, Switching frequency=25kHz. Make suitable assumptions	3	4	4
	(b) An inductor is constructed with a U-shaped ferrite core. The core has an area of cross section 200mm2 and mean magnetic path length of 12 cm. The relative permeability of the core is 3000. Calculate the inductance when 55 turns are used for the coil. What is the value of inductance when an air-gap of 4mm is introduced in the flux path?	4	4	2
10	(a) Design and select each component of a suitable dc-dc converter with input voltage 100V and output voltage of 10V. Output power = 2000W. Switching frequency 10 kHz, Assume all other required data. Justify your selection of components.	3	5	4
	(b) Draw the circuit diagram of a forward converter operating at 50kHz, power being drawn from 230V, 50Hz mains. Identify the possible conducted noise emission sources and explain the means to reduce EMI	4	5	1

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

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

Preamble:

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

Course Outcomes:

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

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

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

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

End Semester Examination Pattern:

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

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

Model Question paper

Model Question Paper
PAGES: 2

QP CODE:XXXXX

Reg.No:______________ Name:___________________

SLOT: D

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

Course Code: **222EEE009**

Course Name: **ELECTRIC VEHICLE SYSTEM DESIGN**

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

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

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

of inertia assuming a gear efficiency of 97%.

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

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

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

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

a) Motoring up a hill and developing full torque at rated speed

b) Cruising and developing 70 Nm at the rated speed

c) Cruising and developing 70 Nm at half the rated speed.

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

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

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

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

Syllabus:

Module 1 (9 hours):

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

Module 2 (8 hours):

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

Module 3 (9 hours):

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

Module 4 (9 hours):

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

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

Module 5 (7 hours):

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

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

Course Plan

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

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

References

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

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

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

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

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

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

Course Outcomes:

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

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

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

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

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

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

End Semester Examination Pattern:

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

Model Question paper

QP CODE: **PAGES: 2**

Reg No:_____________ **Name:_______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, MONTH & YEAR

Course name: Energy Efficiency in Electrical Systems

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

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

1) State the meaning and need of Energy Conservation.

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

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

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

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

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

6) Explain the impact of energy usage on climate.

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

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

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

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

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

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

12) Explain different energy efficient lighting control with features.

Syllabus

Module 1: Energy Scenario:

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

Module 2: Energy Efficiency in Electrical Supply System and Motors

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

Module 3: Energy Efficiency in Electrical Utilities

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

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

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

Module 5 :Energy Efficient Technologies in Electrical Systems

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

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

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

Reference Books

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

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

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

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

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

Important Links:

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

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

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

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

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

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

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

Preamble:

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

Course Outcomes:

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

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

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

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

Continuous Internal Evaluation Pattern:

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

End Semester Examination Pattern:

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

Model Question paper

APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M.TECH DEGREE EXAMINATION

MONTH &YEAR

Course code: 222EEE071

Course Name: Electric Charging Systems for Electric Vehicles

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

PART A

(Answer all questions. Each question carries 5 marks)

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

PART –B

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

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

Syllabus

Module 1- AC-DC converters

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

Module 2- DC-DC converters

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

Module 3- Energy storage

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

Module 4- Charging infrastructure

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

Module 5- Charging Standards

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

COURSE PLAN

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

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

Text books:

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

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

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

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

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

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

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

Test paper shall include minimum 80% of the syllabus.

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

Model Question paper

QP Code:
Name:
Reg No:

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

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

PART A (5 x 5 = 25 Marks)

Answer all Questions. Each question carries 5 Marks

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

Module 5

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

PART B (7 x 5 = 35 Marks)

Answer any five full questions. Each question carries 7 Marks

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

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

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

Syllabus and Corse Plan

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

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

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

Text Books

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

References

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

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

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

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

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

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

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

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

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

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

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

Prerequisite: Fundamentals of power electronics and electric drives

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

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

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Continuous Internal Evaluation Pattern: 100 Marks

Regular performance evaluation in the laboratory (Output and record) - 40%

Regular Class Viva-Voce - 20%

Final Assessment - 40%

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

Final Assessment Mark Split up will be as follows:

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

Syllabus

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

Mandatory experiment

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

Hardware Experiments (Minimum five experiments)

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

Simulation (Minimum five simulation studies)

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

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

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

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

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

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

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