Syllabus

CODE	COURSE NAME	CATEGORY	L	T	P	CREDITS
EET292	**NETWORK ANALYSIS AND SYNTHESIS**	**Core (Honors)**	**3**	**1**	**0**	**4**

Preamble : This honors course is designed with the objective of expanding the student's knowledge in network analysis beyond the basic topics. It includes advanced topics in network analysis, basics of filter design and network synthesis concepts. This course would help students to explore more advanced concepts in the analysis of complex networks.

Prerequisite : **EET201 Circuits and Networks**

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

CO 1	Apply network topology concepts in the formulation and solution of electric network problems.
CO 2	Apply two-port network analysis in the design and analysis of filter and attenuator networks.
CO 3	Identify the properties and characteristics of network functions, and verify the mathematical constraints for their physical realisation.
CO 4	Synthesize passive one-port networks using standard Foster and Cauer forms.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	3										2
CO 2	3	3										2
CO 3	3	3										2
CO 4	3	3										2

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember (K1)	15	15	20
Understand (K2)	20	20	50
Apply (K3)	15	15	30
Analyse (K4)	-	-	-
Evaluate (K5)	-	-	-
Create (K6)	-	-	-

End Semester Examination Pattern : There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Model Question Paper

Reg. No.:

Name: **Pages: 4**

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

Course Code: **EET292**

Course Name: Network Analysis and Synthesis

Max. Marks: 100 Time: 3 hrs

Part A

Answer *all* questions. Each question carries 3 marks.

1. Define subgraph, path and a tree, with proper examples.
2. Describe the properties of the complete incidence matrix.
3. What are dual graphs? What is the condition for a network graph to have a dual? Illustrate with an example.
4. Describe a cut-set with an example.
5. Show that the image impedances of a two-port network are given by $Z_{im1} = \sqrt{\frac{AB}{CD}}$ and $Z_{im2} = \sqrt{\frac{BD}{AC}}$.
6. Draw the frequency response curves for ideal and non-ideal low pass filter, band pass filter, band reject filter, and high pass filter respectively.
7. For the pole-zero plot shown in Fig. 1 below, for a network function, identify the function and find its impulse response.
8. List the properties of positive real functions.
9. What are the properties of LC immittance functions.
10. Draw the Foster and Cauer forms of RC networks. (10 x 3 = 30)

Part B

Answer any one full question from each module.
Each question carries 14 Marks.

Module 1

11. (a) Draw the oriented graph of the given network shown in Fig. 2, and identify one tree and its co-tree. Obtain the incidence matrix. (6)

    (b) Find all voltages and branch currents in the network shown in Fig. 3 by node analysis, and applying network graph principles. (8)

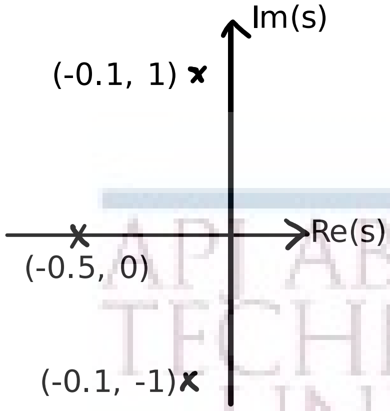


Figure 1: Pole Zero Plot

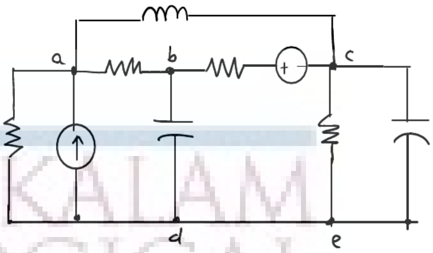


Figure 2: Figure for question 11 (a).

12. (a) The reduced incidence matrix A of an oriented graph is given below. (6)

$$A = \begin{bmatrix} -1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & -1 & 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & -1 & 1 & 0 & -1 \\ 1 & 0 & 1 & 0 & 0 & 0 & -1 & 0 \end{bmatrix}$$

Draw the graph of an electrical network represented by this matrix. The branches constituting the outer loop of are independent current sources branches. All the current sources have their branch current variable at 1 A. Find the currents in all other branches.

(b) Find the total power dissipated in the circuit shown in Fig. 4 by node analysis (graph based). (8)

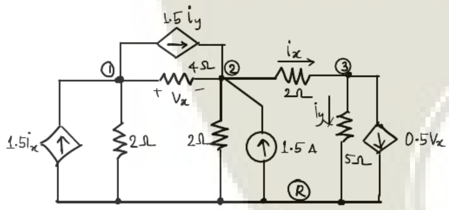


Figure 3: Figure for question 11 (b).

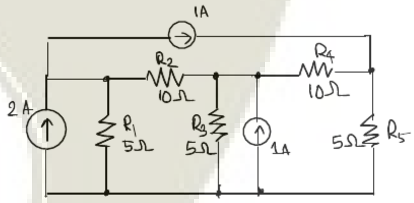


Figure 4: Figure for question 12 (b).

Module 2

13. (a) Find the power delivered by the independent voltage sources in the network shown in Fig. 5 by loop analysis (use graph theory). Prepare the network graph using the reference directions marked in the figure. (8)

(b) A connected network has the fundamental circuit matrix given as, (6)

$$B_f = \begin{bmatrix} 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & -1 & 0 & 0 & 1 & 0 \\ 1 & -1 & -1 & 0 & 0 & 1 \end{bmatrix}$$

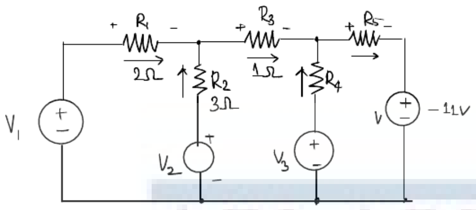


Figure 5: Figure for question 13 (a).

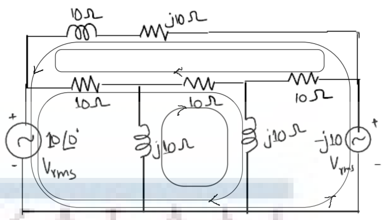


Figure 6: Figure for question 14 (a).

for some choice of tree. Obtain the f-cut-set matrix for the same tree.

14. (a) For the network shown in Fig. 6assign reference directions and draw the network graph. Obtain the connection matrix between branch currents and the loop currents in the three loops shown in the network diagram. Determine the loop impedance matrix of the network. (8)

(b) For the graph shown in Fig. 7, write the cut-set (KCL) equations for the following cut-sets: {1, 6}, {1,2,7,8}, {5, 6, 8, 9} and {2, 5, 7, 9}. Will this set of equations form an independent set of equations? If not why? (6)

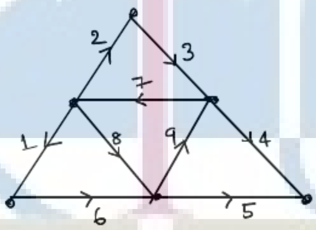


Figure 7: Figure for question 14 (b).

Module 3

15. (a) Design a prototype T-section low-pass filter to cut-off at 100 Hz with a load resistance of 75Ω. Calculate the attenuation in Np and in dB at 200 Hz and 1 kHz. Also find the phase shift suffered by the output signal for 10 Hz and 50 Hz. (7)

(b) Design an m-derived high pass filter having a design impedance of 300 Ω, cut-off frequency of 2000 Hz and infinite attenuation at 1700 Hz. (7)

16. (a) The open-circuit voltage observed across a signal source varies between $\pm 100\ mV$. The voltage across a 60Ω resistance connected across this source is found to vary between $\pm 50\ mV$. Design a T-section attenuator such that the voltage across a 600 Ω load connected across the output of the attenuator varies between $\pm 5\ mV$. (7)

(b) Design the T-section and p-section of a constant K-type BPF that has a pass band from 1500 to 5500 Hz and characteristic resistance of 200 Ω. Further, find resonant frequency of series and shunt arms. (7)

Module 4

17. (a) Test the following polynomials for the Hurwitz property: (6)
(i). $s^3 + s^2 + 2s + 2$
(ii). $s^7 + s^5 + s^3 + s$
(iii). $s^7 + 2s^6 + 2s^5 + s^4 + 4s^3 + 8s^2 + 8s + 4$

(b) Determine whether the following functions are positive real or not: (8)
(i). $F(s) = \dfrac{2s^2 + 2s + 4}{(s + 1)(s^2 + 2)}$
(ii). $F(s) = \dfrac{5s^2 + s}{s^2 + 1}$

18. (a) Find the limits of K so that the polynomial $s^3 + 14s^2 + 56s + K$ may be Hurwitz. (6)

(b) Find the driving point impedance Z(s) in the form $K\dfrac{N(s)}{D(s)}$ for the network shown in Fig. 8. Verify that Z(s) is positive real and that the polynomial D(s)+KN(s) is Hurwitz. (8)

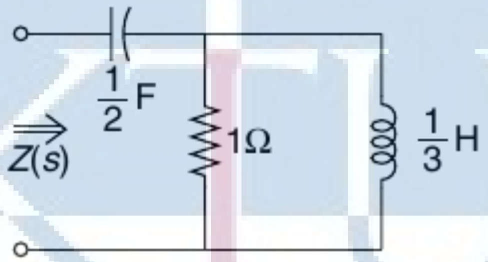


Figure 8: Figure for question 18 (b).

Module 5

19. Realise the impedance $Z(s) = \dfrac{2(s^2 + 1)(s^2 + 0)}{s(s^2 + 4)}$ in three different ways. (14)

20. (a) For the network function $Y(s) = \dfrac{2(s + 1)(s + 3)}{(s + 2)(s + 4)}$, synthesise a Foster form and a Cauer form realisations. (10)

(b) Check whether the driving point impedance $Z(s) = \dfrac{s^4 + s^2 + 1}{s^3 + 2s^2 - 2s + 10}$ represents a passive network or not. (4)

Course Level Assessment Questions

Course Outcome 1 (CO1):

[K1]: Questions on Network topology terminology, definitions.

[K2}: Questions on identification of graphs, paths, sub-paths, etc.,

Questions on incidence matrix.

[K2, K3] Understand level and application level numerical problems on application of Kirchoff's laws in matrix formulation, nodal analysis.

[K2, K3]. Numerical problems on graph theory based network analysis, cut-set, circuit matrices, nodal and loop analysis.

Course Outcome 2 (CO2): [K1, K2] Questions on definitions and properties of filters.

[K2, K3]. Numerical problems on constant-k and m-derived filter design and analysis.

Course Outcome 3 (CO3): [K1] Questions on the properties of network functions and realizability of passive impedance functions.

[K2, K3]. Numerical problems on the realizability of network functions, testing of positive real functions and Hurwitz polynomials.

Course Outcome 4 (CO4): [K1]. Questions to describe Foster and Cauer forms and the properties of immittance functions.

[K2, K3]. Numerical problems to synthesise networks in Foster and Cauer forms.

Syllabus

Module 1

Network Topology (8 hours)

Linear Oriented Graphs -incidence matrix of a linear oriented graph –Kirchoff's Laws in incidence matrix formulation –nodal analysis of networks (independent and dependent sources) – Circuit matrix of linear oriented graph –Kirchoff's laws in fundamental circuit matrix formulation.

Module 2 (8 hours)

Loop analysis of electric networks (with independent and dependent sources) - Planar graphs –Mesh analysis- Duality –Cut set matrix -Fundamental cut set matrix –Relation between circuit, cut set and incidence matrices –Kirchoff's laws in fundamental cut-set formulation –Node-pair analysis – Analysis using generalized branch model (node, loop and node pair analysis) –Tellegen's theorem.

Module 3: (12 hours)

Modeling Two-port networks-application examples-amplifiers, transmission lines, passive filters.

Review of network parameter sets for two-port networks (z, y, h, g, T parameters, equivalent circuits and inter-relationship between parameters). (Review may be done using assignments/homeworks).

Image parameter description of a reciprocal two-port network -- Image impedance - Characteristic impedance - propagation constant—derivation of characteristic impedance and propagation constant for T and Pi networks under sinusoidal steady state -- Attenuation constant and phase constant.

Filter terminology: Low pass, high pass, band-pass and band-reject filters.

Constant k and m-derived filters -- low pass, high pass, band-pass and band-stop filters -- design--effect of cascading multiple sections. Resistive T, Pi and lattice attenuators.

Module 4

Network Functions (10 hours)

Review of Network functions for one port and two port networks: – pole zero location for driving point and transfer functions-Impulse response of Network functions from pole-zero plots- Sinusoidal steady-state frequency response from pole-zero plots.

Hurwitz polynomials –properties - Positive real functions –Properties of positive real functions – passivity-necessary and sufficient conditions for positive real functions-physical realizability.

Module 5

Synthesis of one port networks (8 hours)

Synthesis of reactive one-ports by Foster's and Cauer methods (forms I and II) -Synthesis of LC, RC and RL driving-point functions.

Text Books

1. K. S. Suresh Kumar, "Electric Circuit Analysis", Pearson Publications, 2013.
2. Ravish R. Singh, "Network Analysis and Synthesis", McGraw-Hill Education, 2013

References

1. Franklin Kuo, "Network Analysis and Synthesis", 2nd Ed.,Wiley India.
2. Van Valkenburg M.E., "Introduction to Modern Network Synthesis," Wiley Eastern, 1960 (reprint 1986).
3. Van Valkenburg M.E, "Network Analysis," Prentice Hall India, 2014.
4. Charles A. Desoer and Ernest S. Kuh, "Basic Circuit Theory," Tata McGraw Hill Edition.
5. Chakrabarti, A., "Circuit Theory Analysis and Synthesis", DhanpatRai& Co., Seventh - Revised edition, 2018
6. S. K. Bhattacharya, "Network Analysis and Synthesis," Pearson Education India.

Course Contents and Lecture Schedule:

No	Topic	No. of Lectures
1	**Network Topology (8 hours)**	
1.1	Linear Oriented Graphs - Connected Graph, sub graphs, paths, The incidence matrix of a linear oriented graph – Path matrix, its relation to incidence matrix.	2
1.2	Kirchoff's Laws in incidence matrix formulation – nodal analysis of networks (independent and dependent sources) principle of v-shifting.	2
1.3	Circuit matrix of linear oriented graph – Fundamental Circuit matrix B_f. Relation between All incidence matrix and All Circuit matrix.	2
1.4	Kirchoff's laws in fundamental circuit matrix formulation -	2
2	**(8 hours)**	
2.1	Loop analysis of electric networks (with independent and dependent sources) -- Planar graphs –Mesh analysis- Duality.	2
2.2	Cut set matrix -Fundamental cut set matrix –Relation between circuit, cut set and incidence matrices – Orthogonality relation.	2
2.3	Kirchoff's laws in fundamental cut-set formulation –Node-pair analysis. i-shifting.	2
2.4	Analysis using generalized branch model (node, loop and node pair analysis) –Tellegen's theorem.	2
3	**(13 hours)**	
3.1	Modeling Two-port networks - application examples-amplifiers, transmission lines, passive filters. Review of network parameter sets for two-port networks (z, y, h, g, T parameters, equivalent circuits and inter-relationship between parameters, Standard T- and pi networks. (Review may be done using assignments/homeworks).	2
3.2	Image parameter description of a reciprocal two-port network - Image impedance.	1
3.3	Characteristic impedance - propagation constant—derivation of characteristic impedance and propagation constant for T and Pi networks under sinusoidal steady state -- Attenuation constant and phase constant.	2

3.4	Filter terminology: Low pass, high pass, band-pass and band-reject filters. Gain characteristics. Constant k-derived low pass filter -- Comparison with ideal low-pass filter -- Prototype Low pass filter design.	2
3.5	m-derived low pass filter sections, m-derived half-sections for filter termination. m-derived half-sections for input termination. Half-pi termination for pi section filters.	2
3.6	Constant k- and m-derived high pass filters --Design. Constant k- band-pass filter -- Design of prototype bandpass filter -- Constant-k band-stop filter-effect of cascading multiple sections.	2
3.7	Resistive attenuators-Symmetric T and Pi section attenuators -- Lattice-section attenuator- Symmetrical bridged T-section attenuator - Asymmetrical T-Section and Pi-section attenuator.	2
4	**Network Functions (7 hours)**	
4.1	Review of Network functions for one port and two port networks: – calculation of network functions for ladder and general networks-poles and zeros for network functions-pole zero location for driving point and transfer functions.	2
	Impulse response of Network functions from pole-zero plots- Sinusoidal steady-state frequency response from pole-zero plots.	2
	Hurwitz polynomials – properties - Positive real functions – Properties of positive real functions – passivity-necessary and sufficient conditions for positive real functions - physical realizability.	3
5	**Synthesis of one port networks (9 hours)**	
5.1	Synthesis of reactive one - ports by Foster's and Cauer methods (forms I and II): Synthesis of R–C Network -- Properties of the R–C Impedance or R–L Admittance Function -- Foster Form-I of R–C Network -- Foster Form-II of R–C Network, Cauer Forms of R–C Network.	3
5.2	Synthesis of R–L Network -- Properties of R–L Function/R–C Admittance Function -- Foster Form-I of R–L Network -- Foster Form-II of R–L Network -- Cauer Form-I of R–L Network -- Cauer Form-II R–L Network.	3
5.3	Synthesis of L–C Networks -- Properties of L–C Immittance -- Foster Form-I of L–C Network -- Foster Form-II of L–C Network -- Cauer Form-I of L–C Network -- Cauer Form-II of L–C Network.	3

CODE	COURSE NAME	CATEGORY	L	T	P	CREDITS
EET393	DIGITAL SIMULATION	VAC	3	1	0	4

Preamble: Numerical simulation using digital computers is an indispensable tool for electrical engineers. This honours course is designed with the objective of providing a foundation to the theory behind Numerical Simulation of electrical engineering systems and to give an overview of different styles of simulation tools and methodologies. This course would help students to explore and effectively use simulation tools with a clear understanding of their inner engines. This course also prepares students to explore and use the industry-standard tools like MATLAB and SPICE.

Prerequisites : **1. EET201 Circuits and Networks**

2. EET 205: Analog Electronics

3. MAT 204: Probability, Random Processes and Numerical Methods

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

CO 1	Formulate circuit analysis matrices for computer solution.
CO 2	Apply numerical methods for transient simulation.
CO 3	Develop circuit files for SPICE simulation of circuits.
CO 4	Develop MATLAB/Simulink programs for simulation of simple dynamic systems.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	3		2	3							2
CO 2	3	3		2	3							2
CO 3	3	3		2	3							2
CO 4	3	3		2	3							2

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**		**End Semester Examination**
	1	**2**	
Remember (K1)	15	15	20
Understand (K2)	20	20	50
Apply (K3)	15	15	30

Analyse (K4)	-	-	-
Evaluate (K5)	-	-	-
Create (K6)	-	-	-

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contains 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

Problems on Circuit Analysis Matrix Formulation for Computer Solution (MNA and Sparse Tableau Approach) - K1 and K2 Level questions to be asked.

Writing code snippets in pseudo codes/Flow - charts for simple circuit formulations - K2, K3 Level.

Course Outcome 2 (CO2):

Explain the features of different numerical algorithms with respect to the requirements of circuit simulation: Questions in K1, K2 and K3 Level.

Compare the features of numerical simulation algorithms. Numerical problems and questions in K1, K2 and K3 levels.

Explain the application-specific features of numerical methods in circuit simulation: Adaptive Step-Size, Artificial Ringing and damping - K1 and K2 level questions.

Course Outcome 3 (CO3):

Write circuit files for simple analogue passive and active circuits using standard SPICE notation. K1, K2 and K3 Level questions.

Course Outcome 4 (CO4):

Develop MATLAB scripts for solution of simple ODEs - K2, K3 level questions.

Develop Simulink signal-flow diagrams for simulation of second order, first-order passive networks. K2, K3 Level question.

Model Question paper

QP CODE: PAGES: 4

Reg. No:______________

Name:______________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIFTH SEMESTER B.TECH DEGREE EXAMINATION,

MONTH & YEAR

Course Code: EE393 Course Name: DIGITAL SIMULATION

Max. Marks: 100 Duration: 3 Hours

PART A (3 x 10 = 30 Marks)

Answer all Questions. Each question carries 3 Marks

1. Differentiate between DC simulation and Transient Simulation.
2. What is "convergence issue" in circuit simulation?
3. Differentiate between implicit and explicit numerical methods.
4. Define Local Truncation Error.
5. What is a "stiff system"? Give an example.
6. It is required to simulate a circuit with excessively oscillatory response. Out of Euler method and Trapezoidal method, which is suitable for this system, and why?
7. Write the SPICE circuit file to run the transient simulation of an RC circuit excited by a pulse source of amplitude 5 V and frequency 1 kHz. The RC time constant is 0.1 ms (You may choose any R, C values that satisfy this requirement). Use end time of 1 s. Assume any missing information appropriately.
8. Differentiate between ' .lib' and '.inc' SPICE directives?
9. What is the output of the following MATLAB code:?

```
b = [3 8 9 4 7 5];
sum1 = 0;
for k = 1:4
        sum1 = sum1+b(k);
        end
sum1
```

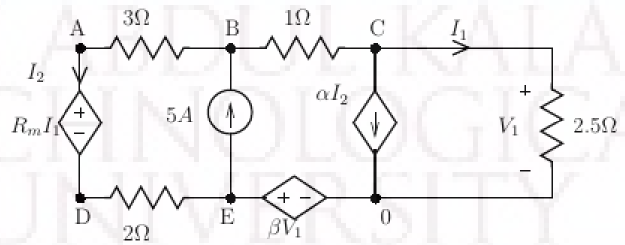
10. Write a MATLAB function to accept the coefficients of a quadratic polynomial and return the evaluated roots.

PART B (14 x 5 = 70 Marks)

Answer any one full question from each module. Each question carries 14 marks.

Module 1

11. (a).Figure 1 shows a network, with α=2, β=0.4 and R_m= 1 Ω. Formulate the Modified Nodal Analysis matrix from fundamental equations. (10)



(b). Explain how 'damping' can be used to improve convergence in nonlinear equation solutions using Newton-Raphson method. (4)

12. (a). For the circuit shown in Fig. 2, formulate the Sparse Tableau Analysis (STA) matrix from the fundamental equations. Take α=0.5. (10)

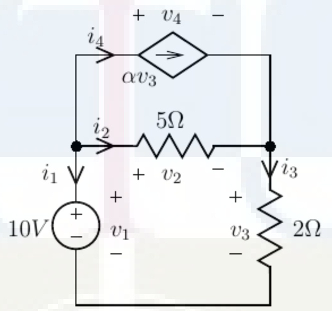


Figure 2: $\alpha = 0.5$

(b). What is Sensitivity Analysis? Explain with an example. (4)

Module 2

13. Solve

$\frac{dx}{dt} = -\frac{1}{2}x - 6te^{-t/2}$, 0 < t < 20, x_0=3, for h = 0.01 and h= 0.05 using Trapezoidal method and forward Euler methods. Compare with the analytical solution $\hat{x}(t) = (2 - 3t^2)e^{-t/2}$. Find the global error at the final value. (14)

14. (a) What is 'Order' of a numerical method? Explain how order and step-size influence the accuracy and computational efficiency of numerical methods. (8)

(b). What are the sources of error in numerical methods? (6)

Module 3

15. Write the MNA equations for the circuit shown in Fig. 3 below: Apply Trapezoidal method on the resulting equations to obtain the corresponding numerical equations.

(14)

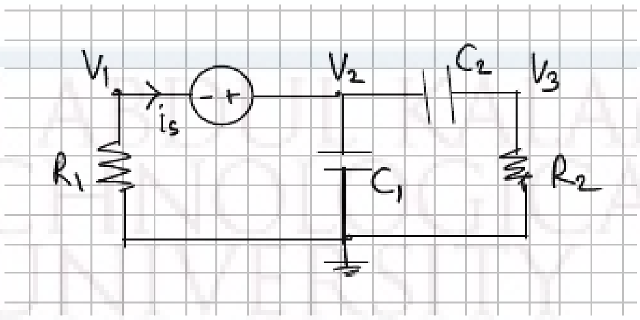


Fig. 3.

16. (a). Explain adaptive step-size in numerical simulation. What methodologies are used for adaptive step-size simulation? (10)

(b). What is 'artificial damping'? Explain with an example.

(4)

Module 4

17. (a). Explain the use of .SUBCKT with an example, where the sub-circuit is an RC integrator circuit to be used in cascade with an RC differentiating circuit. The source is a pulse source of 5 V amplitude and 1 kHz frequency. Assume suitable values for the resistors and capacitors. Use an ideal pulse with no rise time, fall-time, delay time etc. Under what conditions/circumstances do you use a .MODEL instead of a .SUBCKT in a circuit simulation? (8)

(b). Write the circuit file for an RC coupled amplifier with npn transistors. Use suitable values for the circuit parameters. The simulation is to be set up for frequency response analysis. (6).

18. (a). Shown below is a SPICE circuit file/netlist. Inspect the circuit file description and draw the circuit. What kind of simulation is being intended here? Modify this with the source replaced by a single sine wave source of 1kHz and 0.5 mA amplitude, for a transient simulation with end time of 0.1 sec, and a maximum step size of 1 us.

(8)

```
L1 OUT 0 1µ
C1 OUT 0 420p
L2 IN 0 1µ
C2 IN 0 420p
C3 OUT IN {C}
R1 OUT 0 300
I1 0 IN 0 AC 5m
```

```
R2 IN 0 300
.ac oct 200 5Meg 10Meg
.step param C 50p 150p 50p
.end
```

(b). Demonstrate the use of the SPICE directives: ".OP, .PARAM, and .IC" with suitable examples. (6).

Module 5

19. (a)Write a MATLAB function to solve an initial value problem given by: $\dot{x} = x - t^2 + 1;\ 0 \leqslant t \leqslant 2;\ x(0) = 0.5$, using the Trapezoidal method. The function should get the initial value, final value and the step through arguments. Modify this code to solve any general function described in another file, named fx.m? (8)

(b). Develop the simulation signal-flow diagram for the simulation of a parallel RLC network excited by a current source, from the fundamental equations. Use standard blocks such as gain, sum/difference, integrators etc. (6)

20. Develop a simulation (signal-flow) diagram for a DC series motor fed from a dc voltage source and connected to a mechanical load. Take k_b as the back-emf constant and k_t as the torque constant of the motor, R_a the armature resistance, L_a the armature inductance, R_f, L_f are the field resistance and inductance respectively, J is the combined moment of inertia, and B is the viscous friction constant. The simulation diagram should show how the armature current i_a and the speed ω are derived. Show all the relevant equations from which the diagram is derived. (14)

Syllabus

Module 1 (9 Hrs)

Introduction to Simulation:

Types of simulation problems - DC Simulation - Transient Simulation - AC Simulation - Digital Circuit Simulation - Sensitivity Analysis - Noise Analysis. Examples.

Problem formulation for circuit simulation:

Nodal Analysis - General Rules/Steps to form the admittance matrix. Sample problems on formulation of the matrix.

Modified Nodal Analysis (MNA) - General Rules/Steps to form the admittance matrix. Sample problems on formulation of the matrix. (Assignments/Course projects may be assigned for writing code to formulate the Matrix using any high-level language). Formulation Examples.

Sparse Tableau Approach - Formulation of STA matrix. Features and comparison with MNA approach. Formulation Examples.

Non-linear Circuits: Application of the Newton-Raphson method - General procedure for n-th order system of equations - Formulation of Jacobian - Examples - Resources required for simulation: Computation time.

Convergence issues -

Practical Limits due to finite precision. Damping.

(Assignments/Course projects may be given for writing code to formulate the Matrix using any high-level language/pseudo code).

Module 2 (7 hours)

Fundamental Theory behind Transient Simulation:

Introduction to transient simulation: Discretization of time, idea of time - step. - Review of backward Euler, forward Euler and trapezoidal methods.

Basic ideas of Accuracy and Stability (Qualitative description only) of methods of transient analysis using numerical techniques.

Basic ideas of Explicit and Implicit methods:

Concept of 'order' of a numerical method, Local Error (LE), Local Truncation Error (LTE) and Global Error. (No detailed derivations needed).

Module 3: (9 hours)

Application to Circuit Simulation:

Application to circuit simulation: Using BE and TRZ methods. - Second order Backward Difference Formula (BDF-2/Gear Formula, no derivation required). Equivalent Circuit Approach- Stiff systems - Features - Simple Examples.

Basic ideas behind Adaptive/variable step-size. (Qualitative treatment only).

Practical aspects in choosing numerical methods: Artificial damping and ringing induced by numerical algorithms - Assessment of accuracy -- The issue of Singular Matrix in initial/start-up condition.

Module 4

Introduction to SPICE: (10 Hrs).

Types of simulation tools: Circuit simulation tools: SPICE, equation solvers: MATLAB®/Scilab®/Octave - Features, similarities and differences.

Circuit Simulation using SPICE.

Writing SPICE circuit files: SPICE Syntax - SPICE directives (Dot commands: .END, .FUNC, .NET .OPTIONS)

Performing different kinds of simulation and analysis - DC, DC sweep, AC, Transient and noise analyses. (Use of .OP, .PARAM, .TRAN, .DC, .STEP, .IC .MEASURE, .FOUR, .NOISE, .TEMP, .WAVE)

Developing circuit files for simple circuits like CE amplifiers, passive linear/non-linear circuits (Familiar Circuits with R, L, C, Diodes, Transistors).

Developing component models, subcircuits in SPICE. (Use of .MODEL, .SUBCKT, .LIB, .INC, .ENDS directives) - examples (BJTs/MOSFETs).

Simulation Demonstration with simple circuits. Setting-up simulation , and different types of simulation etc. shall be demonstrated by the course instructor.

[LTspice®, a free SPICE version, is chosen here as reference due to wide availability, however, PSpice®, LTspice®, ngSpice, eSim or any available SPICE variants may be used for assignments/demonstrations, based on availability].

Module 5

Introduction to equation solver tools (10 Hrs)

Introduction to scripting using MATLAB®: Language constructs - Basic Arithmetic Operations - Basic Operators and Special Characters Variables and Arrays - Complex numbers -Basic Handling of Arrays (Vectors and Matrices).

Control Structures (Conditional, looping - for loop, while loop, switch-case-otherwise - break -return) - functions.

Numerical Integration - ODE solvers - ode23, ode23t and ode45 - Examples - User-written functions to solve ODEs to implement the algorithms BE, FE, and TRZ only). Application examples. (Performance comparison of different solvers may be given as assignments).

Visual Modelling: Introduction to Simulink/Similar Causal modelling tools. Developing causal simulation diagrams using fundamental blocks (Gain, sum/difference, integrators, etc) for simple circuit models - first-order/second-order circuits, Separately excited DC Motor, from the ODE descriptions. Non-linear examples: DC Series Motor, Simple passive networks with switches.

Simulation Demonstration with different integration algorithms /step-sizes. [Only for practice/assignments].

(Instead of MATLAB/Simulink®, Octave and Scilab®/XCos® may be used for assignments/demonstrations).

Text Books

1. M. B. Patil, V. Ramanarayanan and V. T. Ranganathan, "Simulation of Power Electronic Circuits", Narosa Publishing House.
2. Steven C. Chapra and Raymond P. Canale, "Numerical Methods for Engineers", Tata-McGraw Hill, New Delhi, 2000.

3. Rudra Pratap, “Getting Started with MATLAB®: A Quick Introduction for Scientists & Engineers”, 2010, Oxford University Press.

References

1. LTSpice® [Online] http://www.ltwiki.org
2. MATLAB® [Online] https://in.mathworks.com/help/matlab/
3. Won Y. Yang, Wenwu Cao, Tae-Sang Chung and John Morris, “Applied Numerical Methods Using MATLAB®”

Course Contents and Lecture Schedule:

No	Topic	No. of Lectures
1	**Introduction to Simulation and Problem Formulation. (9 Hrs).**	
1.1	Types of simulation problems - DC Simulation - Transient Simulation - AC Simulation - Digital Circuit Simulation - Sensitivity Analysis - Noise Analysis. Examples.	2
1.2	Problem formulation for circuit simulation: Nodal Analysis - General Rules/Steps to form the admittance matrix. Sample problems on formulation of the matrix. (Assignments/Course projects may be assigned for writing code to formulate the Matrix using any high-level language).	1
1.3	Modified Nodal Analysis (MNA) - General Rules/Steps to form the admittance matrix. Sample problems on formulation of the matrix. (Assignments/Course projects may be assigned for writing code to formulate the Matrix using any high-level language). Examples.	2
1.4	Sparse Tableau Approach - Formulation of STA matrix. Features and comparison with MNA approach. Examples.	1
1.5	Non-linear Circuits: Application of the Newton-Raphson method - General procedure for n-th order system of equations - Formulation of Jacobian - Examples - Resources required for simulation: Computation time.	2
1.6	Convergence issues - Limits due to finite precision. Damping.	1
2	**Fundamental Theory behind Transient Simulation: (7 Hrs).**	
2.1	Introduction to transient simulation: Discretization of time, idea of time - step. - Review of backward Euler, forward Euler and trapezoidal	1

	methods.	
2.2	Basic ideas of Accuracy and Stability of methods of transient analysis using numerical techniques.	1
2.3	Basic ideas of Explicit and Implicit methods:	1
2.4	Concept of Order of a numerical method, Local Error (LE), Local Truncation Error (LTE) and Global Error.	4
3.	**Application to Circuit Simulation (9 Hrs)**	
3.1	Application to circuit simulation: Using Backward Euler, Trapezoidal and Second order backward differentiation formula (BDF2 - Gear's formula) methods in circuit simulation: Equivalent Circuit Approach - Equation formulation examples.	4
3.2	Stiff systems - Features - Examples.	1
3.3	Basic ideas behind Adaptive/variable step-size. (Qualitative treatment only).	1
3.4	Practical aspects in choosing numerical methods: Artificial damping and ringing induced by numerical algorithms.	1
3.5	Assessment of accuracy - The issue of Singular Matrix in initial/start-up condition.	2
4	**Introduction to SPICE: (10 Hrs)**	
4.1	Types of simulation tools: Circuit simulation tools: SPICE, equation solvers: MATLAB®/Scilab®/Octave - Features, similarities and differences.	1
4.2	Circuit Simulation using SPICE. Writing SPICE circuit files: SPICE Syntax - SPICE directives (Dot commands: .end, .FUNC, .NET .OPTIONS)	2
4.3	Performing different kinds of simulation - DC, DC sweep, AC, Transient and noise analyses. (.op, .param, .tran, .dc, .STEP, .IC .MEASURE, .FOUR, .NOISE, .TEMP, .WAVE	2
4.4	Developing simple circuit files for sample circuits like CE amplifier, passive linear/non-linear circuits (Familiar Circuits with R, L, C, Diodes).	2
4.5	Developing component models, sub-circuits in SPICE. (.model, .subckt, .lib, .inc, .ends directives) Example problems. Using datasheets to develop component models - examples (BJTs/MOSFETs) - Exercises.	2

4.6	Simulation Demonstration with simple circuits. Setting-up simulation, and different types of simulation etc., shall be demonstrated by the course instructor. Students shall be given SPICE circuit simulation assignments. [LTspice®, a freeware SPICE version, is chosen here as reference due to wide availability, however, PSpice®, LTspice®, ngSpice or any available SPICE variants may be used for assignments/demonstrations].	1
5.	**Introduction to MATLAB®/Simulink® (10 Hrs)**	
5.1	Introduction to MATLAB® scripting. Language constructs - Basic Arithmetic Operations - Basic Operators and Special Characters - Variables and Arrays - Complex numbers - Basic Handling of Arrays (Vectors and Matrices).	2
5.2	Control Structures (Conditional, looping - for loop, while loop, switch-case-otherwise - break - return) - functions.	2
5.3	Numerical Integration - ODE solvers - ode23, ode23t and ode45 - Examples	1
5.4	User-written functions to solve ODEs to implement the algorithms BE, FE, and TRZ only). Application examples. (Performance comparison of different solvers may be given as assignments).	2
5.5	Visual Modelling: Introduction to Simulink. Developing causal simulation diagrams using fundamental blocks for simple circuit models - first-order/second-order circuits, Separately excited DC Motor, from the ODE descriptions.	2
5.6	Demonstration of simulation examples with different integration algorithms /step-sizes. [Only demonstration/practice/assignments]. (Instead of MATLAB®/Simulink®, Octave and Scilab®/XCos® may be used for assignments/demonstrations).	1

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET394	**GENERALIZED MACHINE THEORY**	**VAC**	**4**	**0**	**0**	**4**

Preamble: Nil

Prerequisite: DC Machines and Transformers. Synchronous and Induction machines

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

CO 1	Develop the basic two pole model representation of electrical machines using the basic concepts of generalized theory.
CO 2	Develop the linear transformation equations of rotating electrical machines incorporating the concept of power invariance.
CO 3	Apply linear transformation for the steady state and transient analysis of different types of rotating electrical machines.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	2	2	2	-	-	-	-	-	-	-	-	**2**
CO 2	3	3	2	**2**	-	-	-	-	-	-	-	**2**
CO 3	3	3	3	**2**	-	-	-	-	-	-	-	**2**

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**		**End Semester Examination**
Remember	5	5	10
Understand	10	10	20
Apply	35	35	70
Analyse			
Evaluate			
Create			

End Semester Examination Pattern : There will be two parts; Part A and Part B. **Part A** contains 10 questions (each carrying 3 marks) with 2 questions from each module. Students should answer all questions.

Part B contains 2 questions from each module, out of which students should answer any one. Each question can have maximum 2 sub-divisions and carries 14 marks.

Part A: 10 Questions x 3 marks=30 marks, **Part B:** 5 Questions x 14 marks =70 marks

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain Kron's Primitive Machine of rotating electrical machines.
2. Describe the essential features of rotating electrical machines.
3. Draw the basic two pole machine diagram of DC Compound Machine.
4. Develop an expression for the electrical torque of the Kron's Primitive Machine.

Course Outcome 2 (CO2):

1. What are the advantages of having power invariance in transformations.
2. Deduce Parks transformations relating three phase currents to its corresponding d- q axis currents.
3. Draw the generalized model of a DC series machine and derive the voltage equation in matrix form.
4. Explain the physical significance of Park's transformations.

Course Outcome 3 (CO3):

1. Explain the steady state analysis of a separately excited DC motor and derive the expression for electromagnetic torque. Also plot the shunt characteristics and speed versus armature voltage characteristics.
2. Obtain the expression for the steady state torque when balanced poly phase supply is impressed on the stator winding of three phase Induction motor
3. Draw the equivalent circuit of a three phase induction motor with the help of its generalized model.
4. Investigate the transient behaviour of a separately excited DC generator under the following operating condition: sudden application of a step field excitation to the field under no load, i_a =0 and for constant no load speed ω_{r0} and explore the variation of armature voltage.

Model Question paper

QP CODE:

PAGES: 2

Reg.No:______________

Name:________________

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

Course Code: EET394
Course Name: GENERALIZED MACHINE THEORY

Max. Marks: 100 **Duration: 3 Hrs**

PART A

Answer all questions. Each Question Carries 3 marks

1. Sketch the basic two pole representation of the following machines
   i) DC shunt machine with interpoles ii) DC compound machine
2. Explain linear transformations as used in electrical machines.
3. What is Kron's primitive machine?
4. Enumerate the limitations of generalized theory of electrical machines.
5. Derive an expression for rotational mutual inductance or motional inductance of DC generator
6. Derive the transfer function of separately excited DC motor under on no load operation.
7. Draw the power angle characteristics of salient pole and cylindrical rotor synchronous machine.
8. Draw the torque slip characteristics of three phase Induction motor.
9. Explain equivalent circuit of single phase Induction motor.
10. Compare single phase and poly phase Induction motor.

PART B

Answer any one full question from each module. Each question carries 14 marks.

Module 1

11. a) Write the voltage equations for Kron's primitive machine in matrix form. **(9)**
    b) Derive the expression for transformer and speed voltages in the armature along the quadrature axis. **(5)**
12. Derive electrical torque expression of Kron's primitive machine in terms of reluctance and show that no torque is produced by interaction between flux and current on the same axis. **(14**

Module 2

13. Explain Park's transformations to transform currents between a rotating balanced three phase (a, b, c) winding to a pseudo stationary two phase (d, q) winding. Assume equal number of turns on all coils **(14)**

14. a) Explain the physical concept of Park's transformation **(7)**

b) Explain the term invariance of power as applied to electrical machines. Show the power invariance is maintained under this transformation. **(7)**

Module 3

15. a) Derive the voltage and torque equation of a DC series motor from its generalized mathematical model. **(7)**

b) Obtain the steady state analysis of a separately excited DC motor and plot the shunt characteristics. Also derive the expression for torque. **(7)**

16. a) A separately excited DC generator gives a no load output voltage of 240 V at a speed of ωr and a field current of 3 A. Find the generated emf per field ampere, Kg. **(5)**

b) Investigate the transient behaviour of a separately excited DC generator under the following operating condition:

i) Sudden application of a step field excitation to the field under no load, i_a =0 and for constant no load speed ωr0 and explore the variation of armature voltage. **(9)**

Module 4

17) a) Derive the power expression for salient pole synchronous machine in terms of load angle δ and draw the power angle characteristics. **(7)**

b) Derive the voltage equations in matrix form for a three phase synchronous machine with no amortisseurs. **(7)**

18) Derive the equivalent circuit of a poly phase induction motor with the help of its generalized mathematical model. **(14)**

Module 5

19) Derive the electromagnetic torque equations from the primitive machine model of a single phase induction motor by applying cross field theory. **(14)**

20) Explain the double field revolving theory of single phase Induction motor. **(14)**

Syllabus

Module 1

Unified approach to the analysis of electrical machine performance - per unit system - Basic two polemodel of rotating machines- Primitive machine -Conventions -transformer and rotational voltages in the armature voltage and torque equations, resistance, inductance and torque matrix.

Module 2

Transformations-passive linear transformation in machines-invariance of power-transformation from a displaced brush axis-transformation from three phase to two phase and from rotating axes to stationary axes-Physical concept of Park's transformation.

Module 3

DC Machines: Application of generalized theory to separately excited DC generator: steady state and transient analysis, Separately excited DC motor- steady state and transient analysis, Transfer function of separately excited DC generator and motor- DC shunt and series motors: Steady state analysis and characteristics.

Module 4

Synchronous Machines: synchronous machine reactance and time constants-Primitive machine model of synchronous machine with damper windings on both axes. Balanced steady state analysis-power angle curves.

Induction Machines: Primitive machine representation. Transformation- Steady state operation-Equivalent circuit. Torque slip characteristics.

Module 5

Single phase induction motor- Revolving Field Theory equivalent circuit- Voltage and Torque equations-Cross field theory-Comparison between single phase and poly phase induction motor.

Text Books

1) Bhimbra P. S., "Generalized Theory of Electrical Machines", Khanna Publishers, 6thedition, Delhi 2017.
2) Charles V. Johnes, "Unified Theory of Electrical Machines". New York, Plenum Press, 1985.
3) Bernad Adkins, Ronald G Harley, "General theory of AC Machines". London, Springer Publications, 2013.

Reference Books

1) Charles Concordia," Synchronous Machines- Theory and Performance", John Wiley and Sons Incorporate, Newyork.1988.
2) Say M. G., "Introduction to Unified Theory of Electrical Machines", Pitman Publishing, 1978.

3) Alexander SLangsdorf, “Theory of Alternating Current Machinery”, Tata McGraw Hill, 2nd revised edition, 2001.

Course Contents and Lecture Schedule

Sl. No.	Topic	No. of Lectures
1	**Two pole Model (10 Hours)**	
1.1	Introduction- Essentials of rotating machines-Electromechanical energy conversion. Conventions.	1
1.2	Idealised machine diagram of DC Compound machine, DC shunt machine, Synchronous motor, Induction motor, Single phase AC motor.	2
1.3	Per unit system, Advantages of per unit system, Expression for self inductance of a machine, Mutual flux linking.	1
1.4	Transformer and speed voltages in the armature, transformer with movable secondary.	2
1.5	Kron's primitive machine, Leakage flux in machines with more than two windings. Fundamental assumptions.	2
1.6	Voltage equations, Stator field coils, Armature coils, Equations of armature voltage in matrix form,	2
2	**Linear Transformations (8 Hours)**	
2.1	Linear transformation in machines- power invariance, Transformations from a displaced brush axis.	2
2.2	Transformations from three phase to two phase (a,b,c) to (α,β,0) transformation matrix.	3
2.3	Transformation from rotating axes (α,β,0) to stationary axes (d,q,0).	2
2.4	Power invariance: problems on transformations	1
3	**DC Machines (10 Hours)**	
3.1	DC machines, Separately excited DC generators, Rotational mutual inductance, Steady state and transient analysis, Armature terminal voltage.	2
3.2	Transfer function of DC machines, Separately excited generator under no load and loaded condition, Numerical Problems.	2
3.3	Steady state analysis and Shunt characteristics of DC machine.	2

3.4	DC series motor, Schematic diagram of Primitive model, Interconnection between armature and field, Torque and speed expression, Different characteristics.	2
3.5	DC shunt motor, Schematic diagram, primitive model, Steady state analysis, Torque-Current and Speed-Current characteristics, Condition for maximum torque.	2
4	**Synchronous and Three Phase Induction Motors(10 Hours)**	
4.1	Poly phase Synchronous machine, Basic structure, Assumptions, Parameters, Synchronous resistance, inductance and mutual inductance between armature and field.	2
4.2	Armature self-inductance, Armature mutual inductance, General synchronous machine parameters, Amplitude of second harmonic component.	2
4.3	Steady state power angle characteristics, reluctance power, Cylindrical rotor machine and salient pole machine, Phasor diagram, Pull out torque, Maximum power.	2
4.4	Polyphase induction machine, Voltage expression, Transformations fromαβ to d-q and vice versa, Expression for electromagnetic torque.	2
4.5	Steady state analysis, Voltage equation in new variables, Connection matrix,	1
4.6	Equivalent circuit of an induction machine, Short circuited and open circuited two winding transformer.	1
5	**Single Phase Induction Motors(7 Hours)**	
5.1	Single phase induction motor, Basic structure, Assumptions, Primitive Machine Model.	2
5.2	Electrical Performance Equations, Voltage Matrix.	2
5.3	Steady state analysis, Equivalent Circuit	2
5.4	Numerical Problems	1

CODE	COURSE NAME	CATEGORY	L	T	P	CREDITS
EET396	ANALYSIS OF POWER ELECTRONIC CIRCUITS	VAC	3	1	0	4

Preamble: To impart knowledge about analysis and design of various power converters.

**Prerequisite : ** Electric circuit theory

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

CO 1	Choose appropriate power semiconductor device along with its driver circuits and protection.
CO 2	Analyse the operation of controlled rectifier circuits and PWM rectifiers.
CO 3	Analyse inverter circuits with different modulation strategies.
CO 4	Analyse the operation of DC-DC converters andAC voltage controllers.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	3										2
CO 2	3	3										2
CO 3	3	3										2
CO 4	3	3										2

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**		**End Semester Examination**
	1	**2**	
Remember (K1)	10	10	20
Understand (K2)	20	20	40
Apply (K3)	20	20	40
Analyse (K4)			
Evaluate (K5)	-	-	-
Create (K6)	-	-	-

End Semester Examination Pattern : There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1): Choose appropriate power semiconductor device along with its driver circuits and protection.

1. Compare ideal and real power electronic switches. (K1)
2. Explain the static and dynamic characteristics MOSFET and IGBT. (K2)
3. Choose the appropriate power electronic switch for a converter. (K3)
4. Illustrate the operation of driver and snubber circuits for power electronic switches. (K2)
5. Design a heat sink for a power electronic switch. (K3)

Course Outcome 2 (CO2): Analyse the operation of controlled rectifier circuits and PWM rectifiers.

1. Analyse the operation of full and semi converters for single and three phase applications working with RLE loads. (K2), (K3)
2. Analyse the effect of source inductance in full converters. (K2), (K3)
3. Explain the operation of phase controlled rectifiers in inversion mode.(K2)
4. Explain the different topologies and control of PWM rectifiers. (K2)
5. Mathematically show the effect of single phase rectifiers on neutral currents in three phase four wire systems. (K2), (K3)
6.

Course Outcome 3 (CO3): Analyse inverter circuits with different modulation strategies.

1. Analyse the operation of single and three phase inverters with RL loads. (K2), (K3)
2. Explain unipolar and bipolar sinusoidal pulse width modulation. (K2)
3. Design output filters for inverters. (K3)
4. Describe the types and working of multilevel inverters. (K1), (K2)
5. Explain the various current control methods of voltage source inverter. (K2)

Course Outcome 4 (CO4): Analyse the operation of DC- DC converters and AC voltage controllers.

1. Analyse the operation of single, two and four quadrant dc choppers. (K4)
2. Describe the control methods of dc choppers. (K2)
3. Design input filter for dc choppers. (K4)

4. Explain the working of multiphase choppers. (K2)
5. Analyse the operation of three phase ac voltage controllers with R load. (K4)

Model Question paper

QP CODE:

PAGES: 2

Reg. No:______________

Name:_______________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SIXTH SEMESTER B.TECH DEGREE EXAMINATION
MONTH & YEAR
Course Code: EET396

Course Name: ANALYSIS OF POWER ELECTRONIC CIRCUITS

Max. Marks: 100 Duration: 3 Hours

PART A (3 x 10 = 30 Marks)

Answer all Questions. Each question carries 3 Marks

1. Draw and explain a snubber circuit for a power MOSFET.
2. Compare the characteristics of ideal and real switches.
3. Why do the triple harmonics dominate in three phase four wire system with balanced rectifier loads?
4. Derive the expression for output voltage of half wave controlled rectifier with resistive load.
5. What is the significance of common mode voltage in inverters.
6. What are the merits of unipolar modulation technique for inverters over bipolar.
7. Derive an expression for average output voltage in terms of input dc voltage andduty cycle for a step down dc chopper.
8. Using a two phase dc chopper, bring out its advantages compared to a single chopper.
9. Develop the expression for power factor for an ac voltage controller using integral cycle control.
10. List the merits and demerits of Hysteresis current controller.

PART B (14 x 5 = 70 Marks)
Answer any one full question from each module. Each question carries 14 Marks

Module 1

11. a) A 100 V dc supply is connected to a resistance of 7 Ohms through a series static controlled switch. The ON state forward voltage drop of the switch is 2 V. Its forward leakage current in the OFF state is 2 mA. It is operated with a switching frequency of 1 kHz and a duty cycle of 30%. Neglect the switching transition times

and determine the peak and average power dissipation in the switch. Also find the proportion in which this power dissipation is shared between the ON state dissipation and OFF state dissipation. **(5)**

b) Draw and explain the static and dynamic characteristics of IGBT. **(9)**

12. a) Explain the design of a driver circuit for MOSFET. **(7)**

b) A MOSFET that is used in a dc-dc converter is dissipating 50W. The thermal resistance to conduction from the junction to the case is 0.5 deg K/W and the thermal resistance to conduction from the case to the heat sink is 1.5 deg K/W. If the ambient temperature in the neighbourhood of the heat sink is 50 deg C, then calculate the thermal resistance requirement for the heat sink if the junction temperature does not exceed 100 deg C. **(7)**

Module 2

13. a) Derive the input PF of a single phase controlled rectifier with continuous and ripple-free load current. **(6)**

b) With necessary mathematical analysis, show the effect of source inductance on the output voltage of a single phase controlled bridge rectifier. **(8)**

14. a) Describe the working of 3-phase fully controlled converter with the help of circuit diagram. **(6)**

b) A three phase fully controlled bridge converter is connected to 415 V supply, having a reactance of 0.3 Ohm/phase and resistance of 0.05 Ohm/phase. The converter is working in the inversion mode at a firing advance angle of 35 deg. Compute the average generator voltage. Assume I_d = 60 A and thyristor drop = 1.5 V. **(8)**

Module 3

15. A single phase bridge inverter supplies an R-L load with R=10 Ohms and L=50mH from a 220 V dc supply. If the inverter frequency is 50 Hz, calculate i) rms value of fundamental component of load current ii) THD of load current iii) total power delivered to the load and iv) fundamental power output. **(14)**

16. Three single phase H bridge inverter circuits are available. What is the level of multilevel inverter that can be formed using them? Draw its circuit diagram and the important waveforms. Give a table showing the switch combination to be turned ON to get each level. **(14)**

Module 4

17. With a neat circuit diagram and waveforms, explain how four-quadrant operation is achieved in a Type-E Chopper. **(14)**

18. a) Explain the working of two quadrant type-A chopper with relevant waveforms. **(8)**

b) A step up chopper has input voltage of 120V and output voltage of 360 V. Ifthe conducting time of the thyristor chopper is 100 μs, compute the pulse width of output voltage. **(6)**

Module 5

19. A three phase three wire bidirectional controller supplies a star connected resistive load of R=5 Ohms and the line to line input voltage is 210 V, 50 Hz. The firing angle is π/3. Determine i) the rms output phase voltage ii) the input power factor and iii) the expression for the instantaneous output voltage of phase a. **(14)**

20. (a) What are the challenges faced by the conventional rectifier circuits? Justify. **(5)**
(b) Explain the working of any two PWM rectifier circuits to mitigate these issues. With block diagrams, discuss their control strategy. **(9)**

Syllabus

Module 1 (8 hours)

Overview of solid state devices

Characteristics of Ideal and Real switches - Static and Dynamic Characteristicsfor MOSFET and IGBT, Driver circuit and Snubbers for MOSFET and IGBT – Conduction and Switching loss - Power dissipation and selection of heat sink.

Module 2 (10 hours)

Phase controlled Rectifiers

Single-phase converter - full converter and semi converter - analysis with RLE loads – input PF with continuous and ripple free load current - inversion mode – effect of source inductance – Effect of single phase rectifiers on neutral currents in three phase four wire systems.

Three-phase converter - Full converter & semi converter – analysis with RLE loads – continuous conduction only – inversion mode - effect of source inductance –line notching and distortion.

Module 3 (10 hours)

Inverters

Single phase full Bridge Inverters –Analysis with RL load - Three phase bridge inverter - Analysis with delta and star connected RL loads – Common mode voltage; PWM principle - Sinusoidal pulse width modulation- Unipolar and Bipolar modulation, Effect of blanking time on voltage of PWM inverter, output filter design.

Multilevel Inverters

Introduction to Multilevel Inverters – Types – Diode clamped, flying capacitor and cascaded multilevel inverters

Module 4 (7 hours)

DC Choppers

Analysis of DC choppers; Single quadrant, two quadrant and four quadrant choppers, PWM control-Time ratio control – Current limit control, Source filter and its design, multiphase chopper.

Module 5 (6 hours)

AC voltage controllers

Three phase AC Voltage Controllers-Principle, operation and analysis with R loads

Current control of VSI

Current Regulated PWM Voltage Source Inverters - Hysteresis Control - Variable Band Hysteresis Control, Fixed Switching Frequency Current Control

PWM rectifiers

Single phase PWM rectifiers –Basic topologies and control

Text Books

1. Joseph Vithayathil, Power Electronics: Principles and Applications, Tata McGraw Hill 2010.
2. Mohan, Undeland, Robbins, Power Electronics; Converters, Applications and Design. -3rdedition, John Wiley and Sons, 2003.
3. Muhammad H. Rashid, Power Electronics: Circuits, Devices and Applications, Pearson Education, 2013.

Reference Books

1. Krein P. T., Elements of Power Electronics, Oxford University Press, 1998.
2. L. Umanand, Power Electronics – Essentials & Applications, Wiley-India, 2009.
3. M H Rashid (Ed), Power Electronics Handbook: Devices, Circuits and Applications,Academic Press 2010.
4. José Rodríguez, *et al,* Multilevel Inverters: A Survey of Topologies, Controls, and Applications, IEEE Transactions on Industrial Electronics, vol. 49, no. 4, August 2002.

Total Lecture Hours: 45

Course Contents and Lecture Schedule:

No	Topic	No. of Lectures
1	**Overview of solid state devices (8 hours)**	
1.1	Characteristics of Ideal and Real switches	1
1.2	Static and Dynamic Characteristics for MOSFET and IGBT	2
1.3	Driver circuit and Snubbers for MOSFET and IGBT	2
1.4	Conduction and Switching loss	1
1.5	Power dissipation and selection of heat sink	2
2	**Phase controlled Rectifiers (10 hours)**	
2.1	Single-phase converter - full converter and semi converter - analysis with RLE loads	2
2.2	Input PF with continuous and ripple free load current - inversion mode	1
2.3	Effect of source inductance.	1
2.4	Effect of single phase rectifiers on neutral currents in three phase four wire system	1
2.5	Three-phase converter - Full converter & semi converter – analysis with RLE loads - continuous conduction only	2
2.6	Inversion mode - Effect of source inductance	2
2.7	line notching and distortion	1
3	**Inverters (10 Hours)**	
3.1	Single phase full Bridge Inverters – Analysis with RL load	1
3.2	Three phase bridge inverter - Analysis with delta and star connected RL loads – Common mode voltage	2
3.3	PWM principle - Sinusoidal pulse width modulation - Unipolar and Bipolar modulation	2
3.4	Effect of blanking time on voltage of PWM inverter, output filter design	2
	Multilevel Inverters	
5.2	Introduction to Multilevel Inverters – Types – Diode clamped, flying capacitor and cascaded multilevel inverters	3
4	**DC Choppers (7 Hours)**	
4.1	Analysis of DC choppers; Single quadrant, two quadrant and four quadrant choppers	3
4.2	PWM control-Time ratio control – Current limit control	2

4.3	Source filter and its design	1
4.4	Multiphase chopper	1
5	**AC voltage controllers (6 Hours)**	
5.1	Three phase AC Voltage Controllers - Principle, operation and analysis with R loads	2
	Current control of VSI	
5.3	Current Regulated PWM Voltage Source Inverters - Hysteresis Control - Variable Band Hysteresis Control, Fixed Switching Frequency Current Control	2
	PWM rectifiers	
5.4	Single phase PWM rectifiers –Basic topologies and control	2

CODE	COURSE NAME	CATEGORY	L	T	P	CREDITS
EET398	OPERATION AND CONTROL OF POWER SYSTEMS	VAC	3	1	0	4

Preamble: This course introduces analysis techniques for the operation and control of power systems. Load dispatch and scheduling of energy are discussed. Power system security and state estimation are introduced. This course serves as the most important prerequisite of many advanced courses in power systems.

Prerequisite: Power Systems I

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

CO 1	Analyse various methods of generation scheduling.
CO 2	Formulate hydro-thermal scheduling problems.
CO 3	Evaluate power exchange in interconnected power systems.
CO 4	Analyse security issues in power system networks.
CO 5	Analyse various state estimation methods.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	3	2	2								2
CO 2	3	3										2
CO 3	3	3										2
CO 4	3	3	2	2								2
CO 5	3	3										2

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**		**End Semester Examination**
	1	**2**	
Remember (K1)	10	10	10
Understand (K2)	20	20	40
Apply (K3)	20	20	50
Analyse (K4)	-	-	-
Evaluate (K5)	-	-	-
Create (K6)	-	-	-

End Semester Examination Pattern : There will be two parts; Part A and Part B. Part A contains 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which students should answer any one question. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain economic dispatch and unit commitment (K1)
2. Problems on optimal load dispatch (K2, K3)

Course Outcome 2 (CO2):

1. Distinguish between the long term and short term scheduling. (K2)
2. Explain how scheduling of energy can be done with limited supply. (K2, K3)

Course Outcome 3 (CO3):

1. Discuss the advantages and disadvantages of power pools (K2).
2. Explain what do you mean by interchange evaluation with unit commitment (K2, K3).

Course Outcome 4 (CO4):

1. What is system security? Explain the major factors involved in system security (K2)
2. Explain the effects of generator outages in power systems. (K2, K3).

Course Outcome 5 (CO5):

1. Discuss in detail, what do you mean by network observability.(K1)
2. Explain any one method by which bad measurements can be detected. (K2).

Model Question paper

QP CODE:

PAGES: 2

Reg. No:______________
Name:______________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SIXTH SEMESTER B.TECH DEGREE EXAMINATION,
MONTH & YEAR
Course Code: EET398

Course Name: OPERATION AND CONTROL OF POWER SYSTEMS

Max. Marks: 100.Duration: 3 Hours

PART A (3 x 10 = 30 Marks)

Answer all Questions. Each question carries 3 Marks

1. Explain what do you mean by economic dispatch.
2. Discuss the different constraints in unit commitment.
3. Differentiate between long range and short term generation scheduling.
4. Write short notes on pumped storage hydro plants
5. Explain what do you mean by power pools.
6. Write short notes on energy banking.
7. Illustrate the importance of power system security
8. What do you mean by contingency analysis?
9. Elaborate on the importance of state estimation in power system.
10. What are the sources of errors in state estimation?

PART B (14 x 5 = 70 Marks)

Answer any one full question from each module. Each question carries 14 Marks

Module 1

11. What do you mean by optimal load dispatch? Explain any one method by which optimal load dispatch can be done. (14)

12 a. With the help of a flowchart, explain the priority list method of unit commitment. (10)

b. Write notes on security constrained unit commitment. (4)

Module 2

13. a. Explain any one method by which short term hydrothermal co-ordination can be done. (7)

b. Explain how hydroelectric plants are modelled for scheduling problems. (7)

14. a. Explain how scheduling of energy can be done with limited supply. (7)

b. Explain any one method by which hydrothermal scheduling with storage limitation can be done. (7)

Module 3

15. a. Explain the advantages of economy interchange between interconnected utilities. (7)

b. Explain the different types of interchange contracts. (7)

16. a. Discuss the advantages and disadvantages of power pools (7)

b.Explain what do you mean by interchange evaluation with unit commitment. (7)

Module 4

17. With the help of a flowchart, explain contingency analysis using sensitivity factors. (14)

18. a. What is system security? Explain the major factors involved in system security (9)

b. Explain the effects of generator outages in power systems. (5)

Module 5

19. a) Explain how quantities which are not measured can be estimated. (7)

b) Discuss in detail, what do you mean by network observability. (7)

20. a) Explain any one method by which bad measurements can be detected. (10)

b)List out the advantages of state estimation in power systems. (4)

Syllabus

Module 1

Introduction- Optimum load dispatch - First order gradient method base point and participation factors.
Economic dispatch versus unit commitment.
Unit Commitment Solution Methods - Priority-List Methods – SecurityConstrained Unit Commitment.

Module 2

Generation with limited supply-Take or pay fuel supply contract- Introduction to Hydro-thermal coordination-Long range and short range scheduling

Hydro-electric plant models-scheduling energy problems - types of scheduling problems-Scheduling energy - The Hydrothermal Scheduling Problem - Hydro scheduling with storage limitation - Introduction to Pumped storage hydro plants

Module 3

Inter change evaluation and power pools- Interchange contracts – Energy interchange between utilities - Interchange evaluation with unit commitment - Energy banking- power pools.

Module 4

Power system security- Factors Affecting Power System Security - Contingency Analysis: Detection of Network Problems - Generation Outages - Transmission Outages - An Overview of Security Analysis

Module 5

Introduction to State estimation in power system, Maximum Likelihood Weighted Least-Squares Estimation - State Estimation of an AC Network - Sources of Error in State Estimation - Detection and Identification of Bad Measurements - Estimation of Quantities Not Being Measured - Network Observability and Pseudo-measurements - The Use of Phasor Measurement Units (PMUs) - Application of Power Systems State Estimation - Importance of Data Verification and Validation

Text books:

1. Allen J. Wood, Bruce F. Wollenberg&Gerald B. Sheblé, “Power Generation, Operation, and Control”, 3rd Edition, John Wiley & Sons, Inc., Hoboken, New Jersey.

2. John Gainger& William Stevenson, “Power System Analysis”, McGraw-Hill, Inc, , 1994.

References:

1. Ali Abur,Antonio Gómez Expósito, Power System State Estimation:Theory and Implementation, CRC Press, 2004.

Course Contents and Lecture Schedule:

Sl. No.	Topic	No. of Lectures
1	**Load Dispatch (9 hours)**	
1.1	Review of economic load dispatch	1
1.2	Optimum load dispatch	2
1.3	First order gradient method base point and participation factors.	2
1.4	Economic dispatch versus unit commitment - Unit Commitment Solution Methods - Priority-List Methods	2
1.5	Security-Constrained Unit Commitment	2
2	**Generation Scheduling (9 hours)**	

2.1	Generation with limited supply-Take or pay fuel supply contract	2
2.2	Introduction to Hydro-thermal coordination-Long range and short range scheduling	1
2.3	Hydro-electric plant models	1
2.4	Scheduling energy problems - types of scheduling problems- Scheduling energy	2
2.5	The Hydrothermal Scheduling Problem	2
2.6	Introduction to Pumped storage hydro plants	1
3	**Interchange evaluation and power pools (9 Hours)**	
3.1	Interchange Contracts	2
3.2	Energy Interchange between Utilities	2
3.3	Interchange evaluation with unit commitment	1
3.4	Energy banking	2
3.5	Power pools	2
4	**Power system security (7 Hours)**	
4.1	Factors affecting Power System Security	2
4.2	Contingency Analysis	1
4.3	Detection of Network Problems	1
4. 4	Generation Outages	1
4. 5	Transmission Outages	1
4. 6	An overview of Security Analysis	1
5	**State estimation in power system (9 Hours)**	
5.1	State estimation in power system - Maximum Likelihood Weighted Least-Squares Estimation	2
5.2	State Estimation of an AC Network - Sources of Error in State Estimation	2
5.3	Detection and Identification of Bad Measurements	1
5.4	Estimation of Quantities Not Being Measured	1
5.5	Network Observability and Pseudo-measurements	1
5.6	The Use of Phasor Measurement Units (PMUS)	1
5.7	Application of Power Systems State Estimation - Importance of Data Verification and Validation	1

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET495	OPERATION AND CONTROL OF GENERATORS	VAC	3	1	0	4

Preamble: NIL

Prerequisite: EET307 Synchronous and Induction Machines

EET302 Power Systems II

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

CO 1	Identify different types of electric generators and prime movers.
CO 2	Develop the model of synchronous generator and excitation system.
CO 3	Explain the basics of speed governor and AGC
CO 4	Acquire knowledge about Reactive power and voltage control.
CO 5	Describe the construction and principle of operation of Self excited synchronous generator, Wound rotor Induction generator and Permanent Magnet Synchronous generator.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	2	2	1								
CO 2	3	3	2	1								
CO 3	3	3	2	1								
CO 4	3	3	2	1								
CO 5	3	3	2	1								

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**		**End Semester Examination**
	1	**2**	
Remember	10	10	10
Understand	20	20	20
Apply	20	20	70
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Classify ac generators by principles. (PO1, K1)

2. Explain the principle of operation of any one synchronous generator. (PO2, K2)

3. Why short pitch winding is preferred over full pitch winding in synchronous generator. (PO3, K2)

Course Outcome 2 (CO2)

1. Draw the general block diagram of excitation system of synchronous generator and explain the function of each unit. (PO3, K3)

2. Explain the need of power system stabilizer. (PO2, K2)

3. Develop the transient d -q model of a synchronous generator. (PO4, K3)

Course Outcome 3 (CO3):

1. List the limitations of isochronous speed governor. (PO1, K2)

2. Explain the Speed droop Governor with load reference control. (PO2, K1)

3. Numerical problem based on speed governor. (PO4, K4)

Course Outcome 4 (CO4):

1. Explain the function of shunt capacitor and series capacitor in power system. (PO4, K2)

2. Draw the equivalent circuit of SEIG in per unit frequency and speed. (PO3, K3)

3. Explain the principle of operation of cage rotor induction generator. (PO1, K2)

Course Outcome 5 (CO5):

1. Explain the constructional details of wound rotor induction generator. (PO2, K1)

2. Draw the phase coordinate model of permanent magnet synchronous generator. (PO3, K3)

3. Explain the on grid operation of Wound rotor induction generator. (PO4, K2)

Model Question Paper

QP CODE:

Reg. No: _______________

Name : ________________

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

Course Code: EET495

Course Name: Operation and Control of Generators

Max. Marks: 100 Duration: 3 Hours

PART A

Answer all questions. Each question carries 3 marks

1. Explain the features of Homopolar synchronous generator.
2. Draw the ideal model of hydraulic turbine.
3. Develop the model of a static exciter.
4. Define the static and dynamic stability of synchronous generator.
5. Draw the schematic of isochronous speed governor.
6. Write the features of speed droop governor with load frequency control.
7. Explain static var systems.
8. Explain automatic voltage regulation.
9. Explain the autonomous operation of wound rotor induction generator.
10. Derive the emf equation of permanent magnet synchronous generator.

PART B

Answer any one full question from each module. Each question carries 14 marks.

Module 1

11. a) With neat diagram, explain the constructional details of any two types of Synchronous Generators and suggest suitable turbine for them. (9 marks)

    b) Explain the principle of operation of Transverse flux reversal generator. (5 marks)

12. a) Explain the construction and working of linear motion alternator. (6 marks)

    b) Develop the model of steam turbine. (8 marks)

Module 2

13. a) Draw the general block diagram of excitation system of synchronous generator and explain the function of each unit. (8 marks)

    b) Draw and explain the v curve and reactive power capability curve of synchronous generator. (6 marks)

14. a) Explain the solution of instability problem of exciter. (6 marks)

    b) Explain the effect of mechanical transients in synchronous generator. (8 marks)

Module 3

15. a) Two similar alternators operating in parallel have the following data:

    Alternator 1: Capacity 700kW, frequency drops from 50Hz at no load to 48.5 Hz at full load.

    Alternator 2: Capacity 700kW, frequency drops from 50.5Hz at no load to 48 Hz at full load.

    Speed regulation of prime movers is linear in each case.

    i) Calculate how a total load of 1200 kW is shared by each alternator.

    ii) Compute the maximum load that these two units can deliver without over loading either of them. (14 marks)

16. a) Draw the schematic of a primitive speed droop governor and obtain the time response of a generation unit with primitive speed droop governor. Also list its merits. (9 marks)

    b) Explain the operation of AGC in an isolated power system. (5 marks)

Module 4

17. a) Write the physical significance of reactive power. Write the function of shunt

capacitor and shunt reactor in power system. (8 marks)

b) Explain the steady state performance of self-excited induction generator. (6 marks)

18. a) Explain voltage control using synchronous condenser. (6 marks)
b) Explain the principle of cage rotor induction generator. (8 marks)

Module 5

19. a) Obtain the steady state equation and draw the equivalent circuit of wound rotor induction generator. (6 marks)
b) Develop the d-q model of permanent magnet synchronous generator. (8 marks)

20. a) Explain the direct power control of wound rotor induction generator at grid. (6 marks)
b) Explain different practical configurations of permanent magnet synchronous generator and list its characteristics. (8 marks)

Syllabus

Module 1 (7 hours)

Electric Generators: Types of electric generators- Synchronous generators- Permanent magnet synchronous generators, Homopolar synchronous generator. Induction generator- Wound rotor doubly fed Induction generator. Parametric Generators- flux reversal generators, Transverse flux reversal generators and linear motion alternators (Basic principle of working and construction). Generator applications- High power wind generators.

Prime movers- Hydraulic turbines- Basics, ideal model, speed governors. Steam turbines- modelling and speed governors of steam turbine. Wind and gas turbines (basics only).

Module 2 (8 hours)

Excitation system- Brushless Excitation, Exciters- DC, AC and static exciters. Modelling of Exciters: - DC exciter, AC exciter and static exciter.

Compensation of excitation systems- Instability problem of exciter, solution to the instability of exciter, need of the power system stabilizer (PSS).

SG operation at Power Grid- Power/angle characteristics, V-curves, reactive power capability curves, Defining static and dynamic stability of SGs.

SG: Modeling for Transients- d-q model, equivalent circuits. Mechanical transients- response to shaft torque input, forced oscillation. Small disturbance electro mechanical transients (basics only).

Module 3 (7 hours)

Control of Synchronous Generators: General control system, Speed Governing basics- SG with its own load, Isochronous speed governor, The primitive speed -droop governor, load sharing between two SGs with speed- droop governor, speed-droop speed governor with load reference control. Time response of speed governors. Automatic generation control-AGC control of one SG in a two SGs isolated power system, AGC as a multilevel control system.

Module 4 (7 hours)

Reactive power and voltage control- Production and absorption of reactive power. Methods of voltage control: shunt reactors, shunt capacitors, series capacitors, synchronous condensers, static var systems. Automatic voltage regulation concept.

Self-excited induction generators: cage rotor induction machine principle. Self-excitation - Steady state performance of three phase SEIGs, Unbalanced operation of three phase SEIGs

Module 5 (7 hours)

Wound rotor induction generators- construction elements, steady state equations, equivalent circuit, Phasor diagrams. Operation at the grid- stator power versus power angle, rotor power versus power angle and operation at zero slip. Autonomous operation of WRIGs, losses and efficiency, Direct power control of WRIG at grid. Permanent magnet synchronous generator systems. Practical configuration and their characterization-distributed versus concentrated windings. Air gap field distribution, emf and torque. Circuit model-phase coordinate model and d-q model.

Text Books

1. P. Kundur, 'Power system stability and control' Mc Graw-Hill, 1994.
2. Ion Boldea, "Synchronous generators", CRC Press, second edition, 2016.
3. Ion Boldea, "Variable speed generator", CRC Press, second edition, 2016.
4. P.S. Bhimbra, "Generalized theory of electrical machines", Khanna Publishers, 2002.
5. Hadi Saddat, "Power System Analysis", McGraw-Hill, 2002.

Reference Books

1 C. Concordia, "Synchronous Machines",
2 W.D Stevenson, "Elements of Power system analysis", 1995.
3 A.E Fitzgerald and Kingsley, "Electric Machinery", Mc Graw-Hill, Fifth edition, 1990.
4 Edward Wilson Kimbark, "Synchronous Machines",
5 "Power System Stability", - Vol 3:

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Module 1 (7hours)**	
1.1	Types of electric generators- Synchronous generators	1
1.2	Permanent magnet synchronous generators, Homopolar synchronous generator. Induction generator- Wound rotor doubly fed Induction generator.	1
1.3	Parametric Generators- flux reversal generators, Transverse flux reversal generators	1
1.4	Linear motion alternators, Generator applications- High power wind generators.	1
1.5	Hydraulic turbines- Basics, ideal model, speed governors.	1
1.6	Steam turbines-modelling and speed governors of steam turbine.	1
1.7	Wind and gas turbines	
2	**Module 2 (8 Hours)**	
2.1	Brushless Excitation, Exciters- DC, AC and static exciters.	1
2.2	Modelling of Exciters: - DC exciter, AC exciter and static exciter.	1
2.3	Instability problem of exciter, solution to the instability of exciter.	1
2.4	Need of the power system stabilizer (PSS).	1
2.5	SG operation at Power Grid- Power/angle characteristics, V-curves, reactive power capability curves, Defining static and dynamic stability of SGs	1
2.6	SG: Modelling for Transients- d-q model, equivalent circuits.	1
2.7	Mechanical transients- response to shaft torque input, forced oscillation.	1
2.8	Small disturbance electro mechanical transients.	1
3	**Module 3 (7 Hours)**	
3.1	Control of Synchronous Generators: General control system	1
3.2	Speed Governing basics-SG with its own load, Isochronous speed governor.	1
3.3	The primitive speed -droop governor, load sharing between two SGs with speed- droop governor.	1
3.4	Speed-droop speed governor with load reference control.	1
3.5	Time response of speed governors.	1
3.6	Automatic generation control-AGC control of one SG in a two SGs isolated power system.	1
3.7	AGC as a multilevel control system.	1
4	**Module 4 (7 Hours)**	
4.1	Reactive power and voltage control- Production and absorption of reactive power.	1
4.2	Methods of voltage control: shunt reactors, shunt capacitors, series capacitors.	1
4.3	Synchronous condensers, static var systems.	1

4.4	Self-excited induction generators: cage rotor induction machine principle.	1
4.5	Self-excitation -Steady state performance of three phase SEIGs.	2
4.6	Unbalanced operation of three phase SEIGs.	1
5	**Module 5 (7 Hours)**	
5.1	Wound rotor induction generators- construction elements.	1
5.2	Steady state equations, equivalent circuit, phasor diagram.	1
5.3	Operation at the grid-stator power versus power angle, rotor power versus power angle and operation at zero slip.	1
5.4	Autonomous operation of WRIGs, losses and efficiency, Direct power control of WRIG at grid.	1
5.5	Permanent magnet synchronous generator systems- Practical configuration and their characterization-distributed versus concentrated windings.	1
5.6	Air gap field distribution, e.m.f and torque.	1
5.7	Circuit model-phase coordinate model and d-q model.	1

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET497	DYNAMICS OF POWER CONVERTERS	VAC	3	1	0	4

Preamble: The objective of this course is to equip students with the basic tools for analysis and design of controllers for power electronic converters.

Prerequisite: EET306: POWER ELECTRONICS

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

CO 1	Analyse dc-dc converters under steady state.
CO 2	Develop dynamic models of switched power converters using state space averaging and circuit averaging techniques.
CO 3	Derive converter transfer functions.
CO 4	Analyse closed loop controllers for dc-dc power converters.
CO 5	Analyse dc-dc converters operating in discontinuous conduction mode.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	3	2	2								
CO 2	3	3	2	2								
CO 3	3	3	2	2								
CO 4	3	3	2	2								
CO 5	3	3	2	2								

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	20%	20%	20
Understand	40%	40%	50

Apply	30%	30%	30
Analyse	10%	10%	
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have a maximum 2 subdivisions and carry 14 marks.

Course Level Assessment Questions (EET497)

Course Outcome 1 (CO1):

1. Analysis of steady state operation with and without loss elements of basic dc-dc converters: (K1, K2, K3).
2. Develop steady state models of buck, boost and buck-boost converters (K2, K3).
3. Evaluate efficiency/duty ratio etc., for the given converters. (K2, K3).
4. Describe the volt-sec balance and amp-sec balance principles and their limitations. (K1, K2)

Course Outcome 2 (CO2)

1. Describe the significance of models with respect to control. (K1, K2).
2. Develop large-signal models from circuit averaging. (K2 K3)
3. Given large signal models, develop small-signal models by perturbation of circuit model. (K2, K3)
4. Procedural steps in deriving the state-space models. (K2)
5. Procedural steps in deriving the circuit averaged/switch averaged models (K2).

6. Given an averaged model of switch network, develop small-signal circuit models by circuit manipulation. (K2, K3).

Course Outcome 3(CO3):

1. Given a small-signal circuit model, develop transfer functions from it. (K2, K3).
2. Given a transfer function, plot Bode plots and get phase margin, Q, etc. (K2, K3).
3. Describe the features of converter transfer functions (K1, K2).
4. Explain experimental measurement of converter transfer functions. (K1, K2)

Course Outcome 4 (CO4):

1. Describe controller requirements for power converters. (K1, K2, K3)
2. Explain the controller structures like PD, PI and PID type compensators. (K2, K3).
3. Given transfer functions of converters, choose appropriate controllers for specified control requirements using Bode plots. (K2, K3)
4. Given transfer functions of compensators, develop op-amp circuits to realise the transfer functions. (K3).

Course Outcome 5 (CO5):

1. Describe the operation of dc-dc converters in DCM. (K2, K3)
2. Develop voltage transformation ratio for buck and boost converters in DCM. (K2, K3).
3. Develop the large-signal and small signal models for buck and boost converters operating in DCM through circuit averaging method. (K2, K3).(Note: From intermediate circuits/equations, full derivations are lengthy).
4. Interpret the model parameters of DCM small-signal, DC and large signal models. (K2, K3).

Model Question Paper:

Code: EET 497 **Pages:5**

Reg No.:_______________

Name:_________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY EIGHTH SEMESTER

B.TECH DEGREE EXAMINATION,

MONTH & YEAR

Course Code: EET 497

Course Name: DYNAMICS OF POWER CONVERTERS

Max. Marks: 100 **Duration: 3 hours**

PART A

Answer all questions; each question carries 3 marks.

1.	What are the assumptions under which the steady-state analysis of the dc-dc converters is carried out?	(3)
2.	How are semiconductor conduction losses modelled in the steady-state analysis of dc-dc converters?	(3)
3.	Compare State-space averaging and circuit averaging techniques.	(3)
4.	What is the need of small-signal models of dc-dc switched converters?	(3)
5.	What type of converters have a right-half plane zero in their output-to-control transfer function?	(3)
6.	What is the significance of 'Q' in the converter transfer functions? How does it affect the converter dynamics?	(3)
7.	Explain the important controller specifications with respect to design of controllers for dc-dc converters.	(3)
8.	Show the transfer function of a typical PD type compensator. What are the primary objectives of this type of controller?	(3)

9. Develop the voltage transformation ratio of a buck converter operating in discontinuous conduction mode. (3)

10 Explain why discontinuous conduction mode in dc-dc converters is also called complete energy transfer mode? (3)

PART B

Answer any one complete question from each section; each question carries 14 mark

11 (a) A boost converter is operating with an input dc voltage of 100 V. If the operating duty ratio is 0.4 and the operating efficiency is 90%, evaluate the output voltage. (4)

(b) Derive the steady-state equivalent circuit model of a buck-boost converter operating in CCM, assuming the switch has an on-state resistance of R_{on}. Neglect all other losses. (10)

OR

12 (a) A 100 W output buck converter is having a total power loss of 15 W. If the input voltage is 18 V, evaluate the operating duty ratio if the output voltage is 10 V. (4)

(b) Develop the steady-state equivalent circuit model of a buck converter operating in CCM, assuming the switch has an on-state voltage drop of V_T, and the diode has an on-state drop of V_D. Neglect all other losses. (10)

13 (a) Explain the step-by-step procedure to develop the averaged circuit model of dc-dc converters. (4)

(b) A switch network and its small-signal averaged model is shown in the figure 1 below: Plug this model into the ideal boost converter circuit in place of the switch network appropriately and transform into the canonical model. (10)

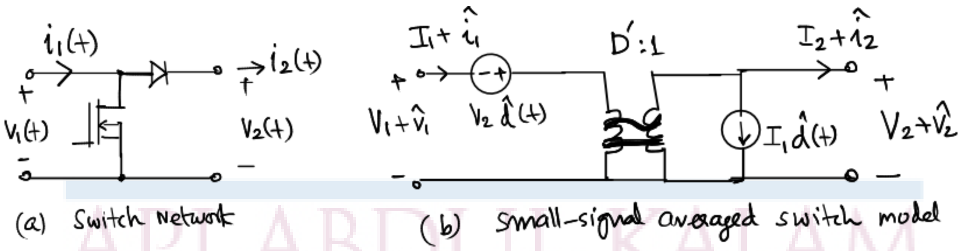


Figure 1.

OR

14 Identify the switch network in the ideal buck converter such that the relative connections between the switch and the diode are not disturbed. Mark port voltages and currents, identify the port voltage and current waveforms, average them and develop an averaged linear model with transformer representation for this switch network (not the converter). (14)

15 (a) Figure 2 shows the small-signal model of a buck converter. Evaluate the output-to-control transfer function, $G_{vd}(s) = \frac{\hat{v}(s)}{\hat{d}(s)}$ from this equivalent circuit, by applying circuit manipulation techniques. Express the transfer functions in the standard form, where the quality factor Q, resonant frequency ω_0, dc gain G_0etc., are visible. (9)

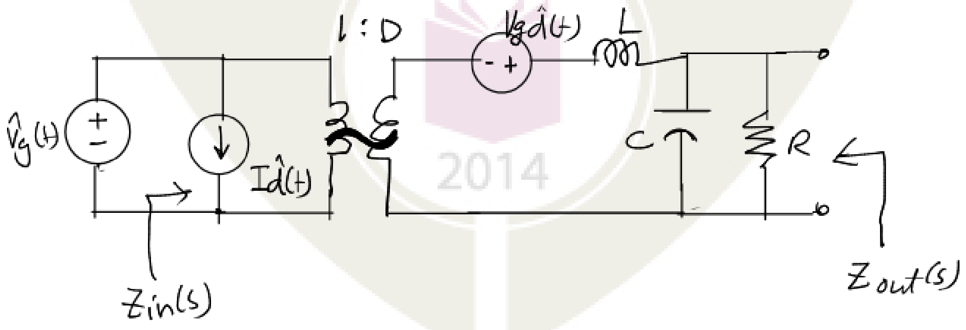


Figure 2.

(b) For the transfer function developed in 15 (a), for a duty ratio D=0.4, L = 100 µH, C= 125 µF and R = 1Ω, evaluate the transfer function. The converter is operated in CCM. Sketch its asymptotic Bode magnitude plot for the frequency range of interest. Comment on the nature of the plot. (5)

OR

16 (a) Describe any one scheme by which the small-signal ac transfer functions of dc-dc power converters can be experimentally measured. (6)

(b) The ideal output-to-control transfer function of a buck-boost converter is given by: (8)

$$G_{vd}(s) = G_{d0}\frac{\left(1-\frac{s}{\omega_z}\right)}{\left(1+\frac{s}{Q\omega_0}+\left(\frac{s}{\omega_0}\right)^2\right)},$$

Where,

$$G_{d0}(s) = \frac{V}{D(1-D)}, \quad \omega_z = \frac{(1-D)^2R}{DL}, \quad \omega_0 = \frac{(1-D)}{\sqrt{LC}}$$, and

$$Q = (1-D)R\sqrt{\frac{C}{L}}$$

For the following specifications, evaluate the transfer function and sketch its asymptotic Bode plots. Label the corner frequencies and the asymptotes appropriately. Vin = 48 V, V =- 24 V; L= 50 µH; C = 220 µF;R= 5Ω.

17 (a) It is desired to design a compensator with the transfer function \$H(s)\$ for a dc-dc converter given by: (7)

$$H(s) = -20\frac{1+\frac{s}{2\pi 800}}{\frac{s}{2\pi 800}}$$

Design the compensator using the ideal Op-amp. What type of controller is this?

(b) Explain the terms voltage injection and current injection with reference to loop gain measurement in dc-dc converters. Show relevant scheme diagrams. (7)

OR

18 Figure 3 shows the block diagram of a closed-loop controlled converter. (14)

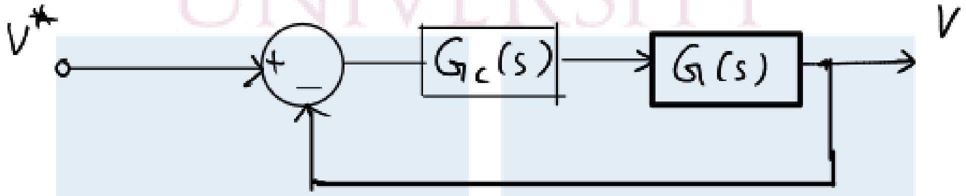


Figure 3.

The converter has a transfer function of

$$G(s) = \frac{40}{1 + \frac{2s}{100\pi} + \frac{s^2}{(100\pi)^2}}$$

The compensator has a transfer function of

$$G_c(s) = \frac{1 + \frac{s}{100\pi}}{1 + \frac{s}{4000\pi}}$$

Sketch the asymptotic gain plots of G(s), H(s) and G(s)H(s), and check whether the closed loop control is stable or not. What is the approximate phase margin of the controller? What is the crossover frequency?

19 (a) The figure following shows the averaged large signal model of a boost converter operating in DCM. What is the significance of the resistor $R_e(D)$, and what does the term P indicate? From this representation, obtain the steady-state expression for voltage transformation ratio in terms of the load resistance R and R_e. (8)

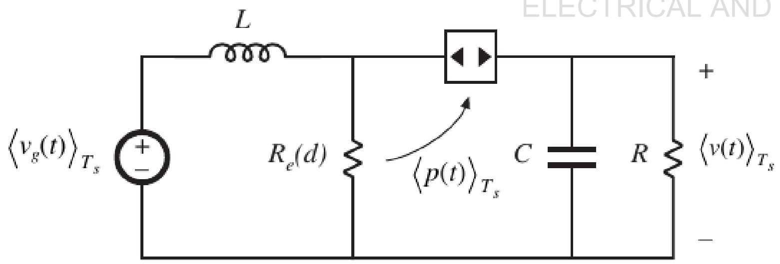
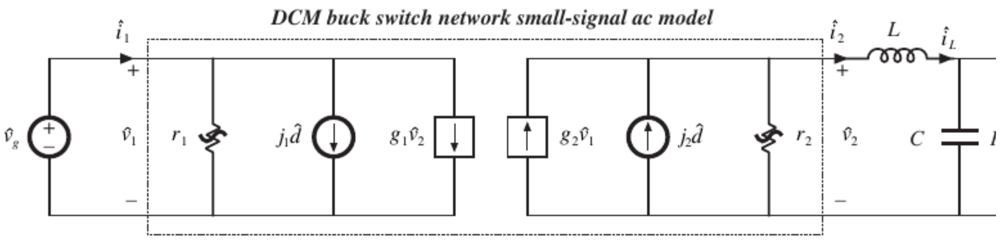


Figure 4.

(b) Write the procedural steps involved in developing the small-signal model for converters operating in DCM. (6)

OR

20 The figure 5 shows the small signal model of a buck converter operated in DCM. Reduce this circuit through circuit analysis techniques and obtain the output-to-line transfer function, Gv(s) = v(s)/v_g(s) in terms of the parameters given in the circuit model. (14)



Syllabus			
Module	**Course Description**	**Hours (45)**	**End Sem exam % Marks**
Module 1	Fundamentals of Steady state converter modelling and analysis applied to basic dc-dc converters: Buck, boost and buck-boost converter - Principle of volt-sec balance, amp-sec balance, and small-ripple approximation - Steady-state (dc) equivalent circuits, losses and efficiency. Inclusion of semiconductor conduction losses in converter model.	**8**	**20**
Module 2	Small-signal AC modelling - Averaging of inductor/capacitor waveforms - perturbation and linearisation. State-Space Averaging-Circuit Averaging and averaged switch modelling- Canonical Circuit Model - Manipulation of dc-dc converters' circuit model into Canonical Form-Modelling the pulse width modulator. *(Treatment may be limited to ideal converters. Questions in the end semester examination may be limited to buck and boost converter).*	**10**	**20**
Module 3	Converter Transfer Functions:- Review of frequency response analysis techniques - Bode plots - Converter transfer functions - graphical construction. Converter transfer functions of ideal buck, boost and buck-boost converters - Measurement of ac transfer functions and impedances.	**8**	**20**
Module 4	Controller Design: Effect of negative feedback on the network transfer functions - loop transfer function- Controller design specifications- PD, PI and PID compensators - applications to the basic dc-dc topologies - Practical methods to measure loop gains: Voltage and current injection.	**10**	**20**
Module 5	Converters in Discontinuous Conduction Mode: AC and DC equivalent circuit modelling of the discontinuous conduction mode-Generalised Switch Averaging-small-signal ac modelling of the DCM switch network. Transfer functions of ideal buck and boost converters in DCM. *(Note: Questions in the end semester examination*	**9**	**20**

	should not demand detailed derivations of transfer functions from scratch, as they're quite lengthy. Instead, intermediate circuits/equations may be provided to ease the time required and test the procedure. Also, form of the transfer functions may be given and asked to interpret/draw bode diagrams).		

Text/Reference Books:

1. Robert Erickson and Dragan Maksimovic, 'Fundamentals of Power Electronics', Springer India, Second Edition.
2. Christophe P. Basso, "Switched Mode Power Supplies: SPICE Simulations and Practical Designs," McGrawhill, Second Edition
3. John. G. Kassakian, M. F. Schlecht, G. C. Verghese, Principles of Power Electronics, PEARSON Education 2010.
4. Ned Mohan, T. M. Undeland, W. P. Robbins, "Power electronics converters, applications and design" 3rd edition, John Wiley and Sons Ltd, 2014.
5. L. Umanand, Power Electronics Essentials and Applications, Wiley publications, 2009.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures (45)
1	**Steady state Modelling (8)**	
1.1	Fundamentals of Steady state converter modelling and analysis applied to basic dc-dc converters:	2
1.2	Buck, boost and buck-boost converter -	2
1.3	Principle of volt-sec balance, amp-sec balance, and small-ripple approximation -	2
1.4	Steady-state (dc) equivalent circuits, losses and efficiency.	1
1.5	Inclusion of semiconductor conduction losses in converter model.	1
2	**Small-signal AC modelling (10)**	
2.1	Averaging of inductor/capacitor waveforms- perturbation and linearisation.	2
2.2	State-Space Averaging-Circuit Averaging and averaged switch modelling-	2
2.3	Canonical Circuit Model-Manipulation of dc-dc converters' circuit model into Canonical Form-	3

2.4	Modelling the pulse width modulator. (Treatment may be limited to ideal converters. Questions in the examination may be limited to buck and boost converter).	3
3	**Converter Transfer Functions (8)**	
3.1	Review of frequency response analysis techniques-	2
3.2	Bode plots –Converter transfer functions-graphical construction.	2
3.3	Converter transfer functions of ideal buck, boost and buck-boost converters -	2
3.4	Measurement of ac transfer functions and impedances.	2
4	**Controller Design (10) :**	
4.1	Effect of negative feedback on the network transfer functions-	2
4.2	loop transfer function-Controller design specifications-	2
4.3	PD, PI and PID compensators - applications to the basic dc-dc topologies -	3
4.4	Practical methods to measure loop gains: Voltage and current injection.	3
5	**Converters in Discontinuous Conduction Mode (8):**	
5.1	AC and DC equivalent circuit modelling of the discontinuous conduction mode-	2
5.2	Generalised Switch Averaging-small-signal ac modelling of the DCM switch network.	3
5.3	Transfer functions of ideal buck and boost converters in DCM	3

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET499	CONTROL AND DYNAMICS OF MICROGRIDS	VAC	3	1	0	4

Preamble: The objective of this course is to introduce the fundamental concepts of dynamics and control of microgrid. This course covers different control strategies for microgrid and their analysis.

Prerequisite: NIL

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

CO 1	Illustrate the basic concept of microgrid and its components
CO 2	Choose proper storage systems for microgrid applications
CO 3	Appraise the operating modes, interconnection standards and issues in microgrid
CO 4	Appraise various control strategies for microgrid
CO 5	Model various components of microgrid

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3		1									3
CO 2	3	3	3				2					2
CO 3	3	2	2		1	1						2
CO 4	3	3	2		1							2
CO 5	3	3	2		2							2

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember (K1)	10	10	30
Understand (K2)	20	20	40
Apply (K3)	20	20	30
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain a microgrid and its components (K1)

2. Illustrate different microgrid architecture. (K2)

3. Appraise the challenges associated with microgrid development. (K2)

Course Outcome 2 (CO2)

1. Explain the working of various energy storage systems with a schematic diagram. (K2)

2. Outline the scope of thermal energy storage systems for a microgrid. (K2)

3. Select suitable storage system for microgrid applications. (K3)

Course Outcome 3(CO3):

1. Distinguish between the grid-connected and islanded modes of operation of a microgrid. (K2)

2. Illustrate the need for IEEE 1547 interconnection standards. (K2)

3. Explain the fault ride-through capability of a microgrid (K1).

Course Outcome 4 (CO4):

1. Compare centralized control and decentralized control in a microgrid. (K2)

2. Choose suitable control strategies for a microgrid. (K3)

3. Explain frequency regulation, voltage regulation and VAR support. (K1)

Course Outcome 5 (CO5):

1. Explain the dynamic modelling of a microgrid. (K2)

2. What are microgrid stabilizers, and explain their design. (K3)

3. Explain the stability aspects of hybrid AC/DC microgrid. (K2)

Model Question Paper

QP CODE: Pages:

Reg No.: _______________

Name: _________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY ------- SEMESTER

B. TECH DEGREE EXAMINATION,

MONTH & YEAR

Course Code:

Course Name: CONTROL AND DYNAMICS OF MICROGRIDS

Max. Marks: 100 **Duration: 3 hours**

PART A

Answer all questions; each question carries 3 marks.

1.	Define a microgrid and list its associated components.	(3)
2.	Explain the technical and economical advantages of a microgrid.	(3)
3.	What is distributed energy storage system?	(3)
4.	What are the key parameters considered for the comparison of energy storage system?	(3)
5.	Explain the integration issues of distributed energy resources in a microgrid	(3)
6.	Explain fault ride-through capability of microgrid	(3)

7. Illustrate droop control of microgrid. (3)

8. What is the benefit of coordinated control in a microgrid ? (3)

9. What are microgrid stabilizers? Explain its necessity. (3)

10. List the advantages of the state-space model of a microgrid. (3)

PART B

Answer any one complete question from each section; each question carries 14 marks

Module 1

11 (a) Compare various microgrid architectures. (6)

(b) Explain the challenges associated with the implementation of a microgrid. (8)

OR

12 (a) Compare the advantages and disadvantages of microgrid deployment. (6)

(b) Explain the operation of a hybrid AC/DC microgrid with a neat diagram. (8)

Module 2

13 (a) Illustrate the working principle of compressed air energy storage system. (7)

(b) Explain flywheel energy storage system with diagram. (7)

OR

14 (a) Identify a suitable energy storage system for momentary support in a microgrid. (8)

(b) Illustrate the working of battery energy storage system. (6)

Module 3

15	(a)	Explain the need for IEEE 1547 standards.	(7)
	(b)	How power management is achieved in a microgrid.	(7)
		OR	
16	(a)	Illustrate various issues with the integration of distributed energy resources in a microgrid and its possible solutions.	(9)
	(b)	What are the conditions to be met in an AC microgrid for the transition from islanded mode to grid connected mode?	(5)

Module 4

17	(a)	Compare the centralized and decentralized control of a microgrid.	(8)
	(b)	Illustrate the advanced control techniques of a microgrid.	(6)
		OR	
18	(a)	Explain the hierarchical control of a microgrid.	(8)
	(b)	What are the various droop control techniques employed in a microgrid? Explain any three methods.	(6)

Module 5

19	(a)	Develop the state space model of a DC microgrid.	(10)
	(b)	What are the benefits of hybrid AC/DC microgrid from a stability aspect?	(4)
		OR	
20	(a)	Develop the state-space model of an AC microgrid.	(10)
	(b)	What is the influence of various parameters on microgrid stability?	(4)

Syllabus

Module 1

Microgrids- Microgrid Concept –Components – Micro sources, loads, power electronic interfaces - Architecture of microgrids (AC/DC/Hybrid AC/DC) – Technical and Economic advantage of microgrids- Challenges and disadvantages of microgrid development.

Module 2

Microgrids and Energy storage systems (ESS)- Different types of Batteries- Advanced lead acid battery, Flow battery, battery performance, storage density, Fuel cell, Flywheel, Supercapacitor, Pumped hydro storage, Superconducting magnetic energy storage, Compressed air energy storage system, Thermal energy storage — Application of energy storage systems in microgrids. PE interface design for energy storage system

Module 3

Operation of microgrid in grid connected and islanded mode – AC microgrid, DC microgrid, Hybrid AC/DC microgrid – Interconnection standards IEEE 1547 series, Integration issues of distributed generation – Power management in microgrids– Fault ride through capability of microgrid

Module 4

Control architectures in microgrid – Master slave with power-based control, Hierarchical control with centralized and distributed control - Basic control strategies – PQ control, V/f control, Droop control – Advanced control techniques- Coordinated control schemes in multi-microgrids, frequency, voltage regulations and volt-VAR support

Module 5

Dynamic modelling of individual components in AC and DC microgrids – Voltage source converter model, DC/DC converter model, line model, load model - state space model analysis and influence of system parameters on the microgrid dynamics - brief concept on the design of microgrid stabilizers to improve stability, Stability of hybrid AC/DC microgrid

Note: It is encouraged to conduct assignments using modern software tools for Module II, Module IV and Module V

Text Books

1. H. Bevrani, B. François, T. Ise, “Microgrid Dynamics and Control”, John Wiley & Sons, 1st Edition, 2017.

2. N. D. Hatziargyriou, “Microgrids Architecture and control”, IEEE Press Series, John Wiley & Sons Inc, 1st Edition, 2013.

Reference Books

1. S. Chowdhury, S P Chowdhury and P Crossely, "Microgrids and active distribution networks", IET Renewable energy series 6.

2. Suleiman M. Sharkh, Mohammad A. Abusara, "Power electronic converters for microgrid", IEEE Wiley

3. Amirnaser Yezdani, and Reza Iravani, Voltage Source Converters in Power Systems: Modeling, Control and Applications, IEEE John Wiley Publications, 2009.

4. Magdi S. Mahmoud, Microgrid: Advanced Control Methods and Renewable Energy System Integration, Elsevier,2017

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Microgrids**	**(6 hours)**
1.1	Microgrid Concept	2
1.2	Microgrid Concept- Components – Micro sources, loads, power electronic interfaces	1
1.3	Architecture of microgrids (AC/DC/Hybrid AC/DC)	1
1.4	Technical and Economic advantage of microgrids- Challenges and disadvantages of microgrid development.	2
2	**Microgrids and ESS**	**(8 hours)**
2.1	Different types of Batteries- Advanced lead acid battery, Flow battery, battery performance, storage density.	2
2.2	Fuel cell, Flywheel, Supercapacitor	1
2.3	Pumped hydro storage, Superconducting magnetic energy storage, Compressed air energy storage system	1
2.4	Thermal energy storage systems	1
2.5	Application of energy storage systems in microgrids.	1
2.6	PE interface design for energy storage system Assignments using software tool for storage system integrated microgrid	2
3	**Operation of microgrid in grid connected and islanded mode**	**(6 hours)**
3.1	Operation of microgrid in grid connected and islanded mode – AC microgrid, DC microgrid, Hybrid AC/DC microgrid	2
3.2	Interconnection standards IEEE 1547 series, Integration issues of distributed generation	1
3.3	Power management in microgrids	1
3.4	Fault ride through capability of microgrid	2
4	**Control architectures in microgrid**	**(8 hours)**
4.1	Master slave with power-based control	1
4.2	Hierarchical control with centralized and distributed control	1

4.3	Basic control strategies – PQ control, V/f control, Droop control	2
4.4	Advanced control techniques- Coordinated control schemes in multi-microgrids	2
4.5	frequency, voltage regulations and volt-VAR support Assignments using software tool to realize basic control strategies.	2
5	**Dynamic modelling of individual components in AC and DC microgrids (10 hours)**	
5.1	Modelling of voltage source converter, DC/DC converter, line model, load model	3
5.2	State space model analysis and influence of system parameters on the microgrid dynamics	1
5.3	Brief concept on the design of microgrid stabilizers to improve stability	3
5.4	Stability of hybrid AC/DC microgrid Assignments using software tool for stability study.	3

EED496	MINI PROJECT	CATEGORY	L	T	P	CREDIT
		PWS	0	0	3	4

Preamble: Mini Project : A Project topic must be selected either from research literature or the students themselves may propose suitable topics in consultation with their guides. The object of Project Work I is to enable the student to take up investigative study in the broad field of Chemical Engineering, either fully theoretical/practical or involving both theoretical and practical work to be assigned by the Department on a group of three/four students, under the guidance of a Supervisor. This is expected to provide a good initiation for the student(s) in R&D work. The assignment to normally include:

- Survey and study of published literature on the assigned topic;
- Preparing an Action Plan for conducting the investigation, including team work;
- Working out a preliminary Approach to the Problem relating to the assigned topic;
- Block level design documentation
- Conducting preliminary Analysis/ Modelling/ Simulation/ Experiment/ Design/ Feasibility;
- Preparing a Written Report on the Study conducted for presentation to the Department;

CO1	Identify and synthesize problems and propose solutions to them.
CO2	Prepare work plan and liaison with the team in completing as per schedule.
CO3	Validate the above solutions by theoretical calculations and through experimental
CO4	Write technical reports and develop proper communication skills.
CO5	Present the data and defend ideas.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3					3	3		2
CO2	3			3				3	3	3	3	
CO3	3	3	3	3	3					3		
CO4					3			3	3	3		1
CO5	3	3	3	3				3		3	3	1

*1-slight/low mapping, 2- moderate/medium mapping, 3-substantial/high mapping

Continuous Internal Evaluation Pattern:

Sl. No.	Level of Evaluation	Marks
1	Interim evaluation by the committee	**20**
2	Project Guide	**30**
3	Final Seminar evaluation by the committee	**30**
4	The report evaluated by the evaluation committee	**20**
	Total	**100**
	Minimum required to pass	**50**

The evaluation committee comprises a panel of HoD or a senior faculty member, Project coordinator and project supervisor.