SEMESTER I

Discipline: ELECTRICAL & ELECTRONICS

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

Course No.	Course Name	L-T-P-Credits	Year of Introduction
221TEE100	LINEAR ALGEBRA AND LINEAR SYSTEMS	3 - 0 - 0	2022

Preamble: Nil

Course Prerequisites

Basic knowledge of engineering mathematics at UG level.

Course Objectives

To equip the student with mathematical techniques necessary for computing applications in engineering systems

Course Outcomes:

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

CO 1	Explain the concepts of vector spaces.
CO 2	Apply linear transformations in linear systems
CO 3	Solve systems of linear equations and interpret their results
CO 4	Solve LTI and LTV Systems
CO 5	Analyse linear systems.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

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

End Semester Examination Pattern:

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving M Tech Regulations, Curriculum 2022 and quantitative evaluation), with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks. Total duration of the examination will be 150 minutes

EE3

Model Question Paper

Pages **SLOT**

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

221TEE100: LINEAR ALGEBRA AND LINEAR SYSTEMS

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

	Part A **(Answer all questions)**	**Marks**
1	How orthogonality is defined between vectors? Check whether the vectors $v_1 = [1, 2, 1], v_2 = [1, -1, 1]$ are orthogonal or not? If $S = \{v_1, v_2, ..., v_n\}$ is the set of n mutually orthogonal vectors what is the dimension of the space spanned by the set S? Justify your answer?	(5)
2	Show that null space is the orthogonal complement of row space of a linear transformation matrix	(5)
3	Show that similarity transformation doses not change the Eigen values of a linear transformation matrix	(5)
4	What are Eigen vectors of a linear transformation? Find a non-singular matrix P such that $P^T AP$ is diagonal $A = \begin{bmatrix} 1 & 1 & 2 \\ 0 & 3 & 2 \\ 1 & 3 & 9 \end{bmatrix}$	(5)
5	Derive the expression for the controllability Grammian matrix of a linear system	(5)
	Part B **(Answer any five questions)**	
6	With the help of a suitable example analyze the stability of a system by pole zero cancellation.	(7)
7	Define inner product space? Consider the following polynomial $P(t)$ with inner product given by $< f, g > = \int_0^1 f(t)g(t)dt$ find i) $< f, g >$ and (ii) $\parallel f \parallel, \parallel g \parallel$ if $f(t) = t + 2, \quad g(t) = 3t - 2$	(7)

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

Text book:

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

References:

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

Syllabus

Module I

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

Module II

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

Module III

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

Module IV

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

Module V

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

Course Plan

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

1.4	Linear Independence	2
1.5	Basis and Dimension	2
2	Linear Transformations	
2.1	Space of Linear Transformations	2
2.2	Matrix representation of linear transformations	3
2.3	Change of Basis and Similarity	3
3	Solutions to Linear System of Equations	
3.1	Rectangular Systems and Echelon Forms	2
3.2	Homogeneous and Non homogeneous systems	2
3.3	Eigenvalues, Eigenvectors, Eigenspaces	2
3.4	Diagonalizability	2
4	Linear Systems	
4.1	Solutions to LTI and LTV Systems	2
4.2	Analysis of stabilization by pole zero cancellation - Initial conditions for Analog- Computer Simulation	2
4.3	Controllability, Controllability Grammians , Stabilizability	2
4.4	Controllable Subspaces, controllable and uncontrollable modes	2
5		

5.1	Reachability and Constructability, Reachable Subspaces	1
5.2	Observability, Observability Grammians	1
5.3	Observable Decomposition, Kalman Decomposition	2
5.4	State feedback Controller Design	2
5.5	Observer Design, separation principle - combined observer controller configuration	2

EE3

221TEE003	POWER SYSTEM DYNAMICS AND CONTROL	CATEGORY	L	T	P	CREDIT
		Program Core 1	3	0	0	3

Preamble:
The main requirement of a power system is to provide reliable supply at rated voltage and frequency. The aim of this course is to familiarize students with how to model a power system for stability.

Prerequisites: Nil

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

CO 1	Analyse power system stability
CO 2	Analyse turbine models and speed governors
CO 3	Derive synchronous machine models
CO 4	Design power system stabilizers to improve stability
CO 5	Analyse transient stability and voltage stability of the system

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

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

Continuous Internal Evaluation: 40 marks
Micro project/Course based project: 20 marks
Course based task/Seminar/Quiz: 10 marks
Test paper, 1 no: 10 marks

The project shall be done individually. Group projects not permitted. Test paper shall include minimum 80% of the syllabus.

End Semester Examination: 60 marks

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

Model Question paper

B

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 20XX

ELECTRICAL AND ELECTRONICS ENGINEERING

Streams: POWER SYSTEMS

221TEE003 POWER SYSTEM DYNAMICS AND CONTROL

Max. Marks: 60 Duration: 2.5 Hours

Part A

Answer ALL Questions

1	Explain the classical model of a single machine infinite bus system.	(5)
2	Draw the functional block diagram of a synchronous machine excitation control system. Explain the function of each block in detail.	(5)
3	Derive the expression for stator-to-stator self-inductance of a synchronous machine with stationary reference	(5)
4	Explain how a power system stabiliser helps in improving stability of a system.	(5)
5	Analyse transient stability enhancement techniques	(5)

(5x5=25 marks)

Part B

Answer any FIVE full Questions

6.	a. Analyse the different stability problems faced by power systems.	(4)
	b. Discuss the shortcomings of the classical model of a single machine infinite bus system.	(3)
7.	Explain how induction motor can be modeled for stability studies.	(7)
8.	Analyse equivalent circuit of a synchronous machine for d-q axes.	(7)

9.	The following are the parameters in pu on machine rating of a 555 MVA, 24 kV, 60 Hz, 3600 rpm turbine generator, $L_{ad} = 1.66$, $L_{aq} = 1.61$, $L_l = 0.15$, $R_a = 0.003$. When the generator is delivering rated MVA at 0.9 pf lag and rated terminal voltage, compute the internal angle δ_i in electrical degree and the pu value of i_{fd} .	(7)
10.	Develop the block diagram of a single machine infinite bus system with exciter and AVR.	(7)
11.	A synchronous generator is connected to an infinite bus through an external reactance, $X_E = 0.4$ pu. Compute the Heffron-Phillips constants K_1 to K_6 at the operating point, $P_g = 0.5$pu, $V_t = 1.0$pu, $E_B = 1.0$pu. The machine data: $X_d = 1.6$pu, $X_q = 1.55$pu, $X'_d = 0.32$pu, $T'_{do} = 6.0$s, H = 5pu, D = 0 and $f_B = 60$ Hz.	(7)
12	a. Explain what do you mean by voltage stability? What causes voltage instability.	(3)
	b. Derive expression for critical clearing angle for a short circuit at sending end for a single machine connected to infinite bus system through a double circuit line.	(4)

Syllabus

Module I: Introduction to Power System Stability

Structure of power system, subsystem of power system controls, States of operation & System Security, classification of power system Stability Problems

Review of Classical Model.

Analysis of Steady State Stability & Transient Stability: Concept of Equilibria, Small and Large Disturbance Stability, Single Machine Infinite Bus System.

Modal Analysis of Linear Systems, Analysis using Numerical Integration Techniques.

Module II: Excitation systems & Prime Mover Controllers

Simplified Representation of Excitation Control, Excitation systems, Modeling, Prime Mover Control System

Modeling of Transmission Lines and Loads: Transmission Line Physical Characteristics, Transmission Line Modeling,

Load Models - induction machine model.

Module III: Modeling of Synchronous Machines

Modeling of Synchronous Machines: Parks transformation of flux linkage equations, voltage equations and physical interpretation, equivalent circuit for d-q axes, per unit representation

Steady state analysis- voltage-current and flux linkage, phasor representation, steady state equivalent circuit

Module IV: Small signal Stability

State space representation concept, Eigen properties of the state vectors, analysis of stability- small signal stability of a single machine connected to infinite bus system.

Classical representation of generator, Heffron-Phillips constants – Effects on Excitation system – Block diagram representation with exciter and AVR – small signal stability enhancement by Power System Stabilizer (PSS)

Module V: Transient stability & Enhancement of System Stability

Operational Measures- Preventive Control, Emergency Control.

Transient stability: Effect of mechanical input change, Equal area criterion, Effect of short circuit at midpoint of one of the transmission lines of double circuit line, short circuit at sending end, critical clearing angle, critical clearing time, Transient stability enhancement techniques

Voltage Stability in Single Machine Load Bus System, voltage collapse and its prevention

Torsional Oscillations

Course Plan

No	Topic	No. of Lectures
1	**Introduction to Power System Stability**	
1.1	Structure of power system, controls, States of operation & System Security	2
1.2	classification of Stability Problems Review of Classical Model.	1
1.3	Analysis of Steady State Stability & Transient Stability: Concept of Equilibria, Small and Large Disturbance Stability, Single Machine Infinite Bus System	2
1.4	Modal Analysis of Linear Systems, Analysis using Numerical Integration Techniques.	3
2	**Excitation systems & Prime Mover Controllers:**	
2.1	Simplified Representation of Excitation Control, Excitation systems, Modeling, Prime Mover Control System	3
2.2	Modeling of Transmission Lines and Loads: Transmission Line Physical Characteristics, Transmission Line Modeling,	3
2.3	Load Models - induction machine model.	3
3	**Modeling of Synchronous Machines**	
3.1	Modeling of Synchronous Machines: flux linkage equations, inductance matrix, voltage equations w r to stationary reference	3
3.2	Parks transformation matrix, d-q transformation, per unit representation, equivalent circuit for d-q axes	3
3.3	Steady state analysis- voltage-current, phasor representation, steady state equivalent circuit	3
4	**Small signal Stability**	
4.1	State space representation concept, Eigen properties of the state vectors, analysis of stability- small signal stability of a single machine connected to infinite bus system.	2
4.2	Classical representation of generator, Heffron-Phillips constants –	2

4.3	Effects on Excitation system – Block diagram representation with exciter and AVR	2
4.4	small signal stability enhancement by Power System Stabilizer (PSS)	1
5	**Transient stability & Enhancement of System Stability:**	
5.1	Operational Measures- Preventive Control, Emergency Control.	1
5.2	Transient stability: Effect of mechanical input change, Equal area criterion, Effect of short circuit at midpoint of one of the transmission lines of double circuit line, short circuit at sending end,	2
5.3	critical clearing angle, critical clearing time, Transient stability enhancement techniques	2
5.4	Voltage stability, voltage collapse& prevention, Torsional Oscillations	2

Text Books

1. K. R. Padiyar, "Power System Dynamics – Stability & Control", II Edition, B.S.Publications.
2. PrabhaKundur, "Power System Stability and Control", Tata McGraw Hill

Reference Books

1. Harry G. Kwatny, Karen Miu-Miller "Power System Dynamics and Control", Springer-Verlag New York Inc.
2. Benjamin C. Kuo, "Automatic Control system", Prentice Hall of India Pvt Ltd
3.P.M. Anderson and A.A. Fouad, "Power system control and stability" John Wiley & sons
4. .J. Nagrath and M. Gopal, "Control system engineering", Wiley Eastern Ltd 3rd edition, 2000.

EE3

221TEE004	Power Electronic Application in Power Systems	CATEGORY	L	T	P	CREDIT
		Program Core 2	3	0	0	3

Preamble:
To impart knowledge on how to utilise various power electronic devices and converters to meet specific purposes in power systems.

Prerequisites: Nil

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

CO 1	Select and interconnect suitable power semiconductor devices for a specific requirement
CO 2	Design of DC-DC converters in renewable energy systems
CO 3	Design of inverter topologies for power system applications
CO 4	Apply power electronics for HV DC transmission
CO 5	Apply power electronics in the Flexible AC transmission systems (FACTS)

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:
Evaluation shall only be based on application, analysis or design-based questions

(For both internal and end semester examinations).

Continuous Internal Evaluation: **40 marks**

Micro project/Course based project: **20 marks**

Course based task/Seminar/Quiz: **10 marks**

Test paper, 1 no.: **10 marks**

The project shall be done individually. Group projects not permitted. Test paper shall include minimum 80% of the syllabus.

EE3

End Semester Examination Pattern:

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

Model Question paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR.

Electrical & Electronics Engineering

(Stream: Power Systems)

221TEE004 Power Electronic Application in Power Systems

Max. Marks: 60 Duration: 2.5 hours

PART A

(Answer all questions. Each question carries 5 Marks)

1	Why is it difficult to achieve an ideal switch characteristic using semiconductor switches?	(5)
2	Differentiate between the continuous and discontinuous conduction modes of DC-DC converters. What are the different factors that decide the two modes and how?	(5)
3	How can selective harmonic elimination be achieved using multiple notches?	(5)
4	What is instantaneous reactive power theory and how can it be used for implementing reactive power compensators?	(5)
5	What is the principle of shunt compensation? How can switched impedance type Var compensators be used for this purpose?	(5)

PART B

(Answer any 5 questions. Each question carries 7 Marks)

6	How are the parameters like voltage, current, and time during a general switching process related to the switching loss?	(7)

7 A regulated output of 5 V is required to derive from an input supply that varies between 20 V and 30 V. The switching is at 50 kHz and is used for supplying a load resistor of 5 Ω. The maximum allowable inductor current ripple is 10% of the load current, and output voltage ripple is 1% of the output voltage. Estimate the value of the series inductance and output capacitor to be used in the buck converter. (7)

8 A buck–boost converter that is switching at 50 kHz is supplied with an input voltage that varies between 5 V and 10 V. The output is required to be regulated at 15 V. A load resistor of 15 Ω is connected across the output. If the maximum allowable inductor current ripple is 10% of the average inductor current, estimate the value of the inductance to be used in the buck–boost converter. (7)

9 How can a hysteresis current controller be used to follow an output reference current? (7)

10 How can a 12-pulse converter be achieved for HVDC application? What are its advantages? (7)

11 Why is it considered that STATCOM can have better control of the reactive power injection compared to switched impedance type Var compensators? Explain (7)

12 Develop the control strategy of a SSSC to act as a power flow controller? (7)

Syllabus

Module 1 (8 Hours)
Power semiconductor switching devices: The ideal switch, characteristics of ideal switches – two quadrants and four-quadrant switches- Switching characteristics of Power Diodes, SCRs, MOSFETs, IGBTs, GTOs thyristors- Conduction loss and switching loss computation, Concept of Soft switching

Module 2 (8 Hours)
Application of DC-DC converters in renewable energy systems: Introduction - Buck, boost, buck-boost and Cuk Topologies-Steady state analysis in continuous conduction mode using inductor volt-sec balance-Design relations for inductor and capacitors, current and voltage ripples - Discontinuous Conduction Mode operation of basic buck and boost converter.

Module 3 (8 Hours)
Inverters for power system applications: Single phase VSI, Three Phase VSI topologies- Pulse width modulated switching schemes-sinusoidal PWM - Selective Harmonic Elimination of Single-phase Voltage source Inverters, Current control methods in Voltage Source Inverters- Introduction to multi-level inverters. – Diode clamped, flying capacitor and cascaded multilevel inverter topologies – the principle of operation and modulation strategies.

Module 4 (8 Hours)
Power electronic converters in HV DC transmission: Power flow control in DC link, Converter and inverter output equations, Graetz circuit- 12-pulse converter. Control of converters. Harmonics and Reactive power in HVDC substations- Reactive power compensator using instantaneous reactive power theory, stationary to rotating reference frame transformation.

Module 5 (8 Hours)
Power electronics in Flexible AC transmission systems (FACTS): AC transmission line model, Principle of shunt compensation – shunt compensators – switched reactor- switched capacitor, static VAR compensator, direct and indirect control of STATCOM- Principle of series compensation – switched series compensators; SSSC.

Course Plan

SNo	Topic	No. of Lectures
1	**Power semiconductor switching devices**	
1.1	The ideal switch, characteristics of ideal switches – two quadrants and four-quadrant switches.	2
1.2	Switching characteristics of Power Diodes, SCRs, MOSFETs, IGBTs, GTOs thyristors,	3
1.3	Conduction loss and switching loss computation, Concept of Soft switching	3
2	**Application of DC-DC converters in renewable energy systems**	
2.1	Introduction - Buck, boost, buck-boost and Cuk Topologies-	2
2.2	Steady state analysis in continuous conduction mode using inductor volt-sec balance	2
2.3	Design relations for inductor and capacitors, current and voltage ripples	2
2.4	Discontinuous Conduction Mode operation of basic buck and boost converter.	2
3	**Inverters for power system applications**	

EE3

3.1	Single phase VSI, Three Phase VSI topologies	1
3.2	Pulse width modulated switching schemes-sinusoidal PWM	2
3.3	Selective Harmonic Elimination of Single-phase Voltage source Inverters, Current control methods in Voltage Source Inverters.	2
3.4	Introduction to multi-level inverters. – Diode clamped, flying capacitor and cascaded multilevel inverter topologies – the principle of operation and modulation strategies.	3
4	**Power electronic converters in HV DC transmission**	
4.1	Power flow control in DC link, Converter and inverter output equations, Graetz circuit.	2
	12-pulse converter. Control of converters. Harmonics and Reactive power in HVDC substations.	2
4.2	Reactive power compensator using instantaneous reactive power theory, stationary to rotating reference frame transformation.	4
5	**Power electronics in Flexible AC transmission systems (FACTS)**	
5.1	AC transmission line model, Principle of shunt compensation – shunt compensators – switched reactor- switched capacitor,	2
5.2	static VAR compensator, direct and indirect control of STATCOM	2
5.3	Principle of series compensation – switched series compensators; SSSC.	4

Text Books

1. Ned Mohan, et al., Power Electronics: Converters, Design and Applications, John Wiley and Sons, 2010

2. L. Umanand, Power Electronics Essentials and Applications, John Wiley and Sons, 2010

Reference Books

1. G. K. Dubey, et al., Thyristorised Power Controllers, New Age International Publishers

2. Muhammed H. Rashid, “Power Electronics”, Prentice Hall of India, Ltd.2004

3. N.G. Hingorani and L.Gyugyi, “Understanding FACTS”, IEEE Press, 2000.

4. K.R. Padiyar, “HVDC Power Transmission Systems”, Wiley Eastern Ltd.

EE3

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221EEE012	**ADVANCED POWER SYSTEM ANALYSIS**	**PROGRAM ELECTIVE 1**	**3**	**0**	**0**	**3**

Preamble: This course discusses advanced topics related to power system analysis. Knowledge about these topics will help students in research and professional careers.

Prerequisites: Nil

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

CO1	Develop suitable models for the analysis of power systems
CO2	Perform the load flow analysis in AC-DC systems
CO3	Analyze the different fault conditions in power systems
CO4	Apply contingency analysis in power systems
CO5	Estimate the state of the power system

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	1	-	3	-	2	-	1
CO2	2	-	3	-	2	-	-
C03	3	-	3	1	3	-	1
C04	2	-	3	1	2	-	-
C05	3	-	3	-	2	-	1

Assessment Pattern

Bloom's Category	Continuous Assessment Test	End Semester Examination
Understand	20	20
Apply	40	40
Analyse	40	40
Evaluate	-	-
Create	-	-

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed:

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

EE3

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

Test paper, 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B.

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

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

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

EE3

Model Question paper

QP CODE: **PAGES:2**

Reg No:_______________ **Name:_______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 221EEE012

Course Name: ADVANCED POWER SYSTEM ANALYSIS

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

PART A

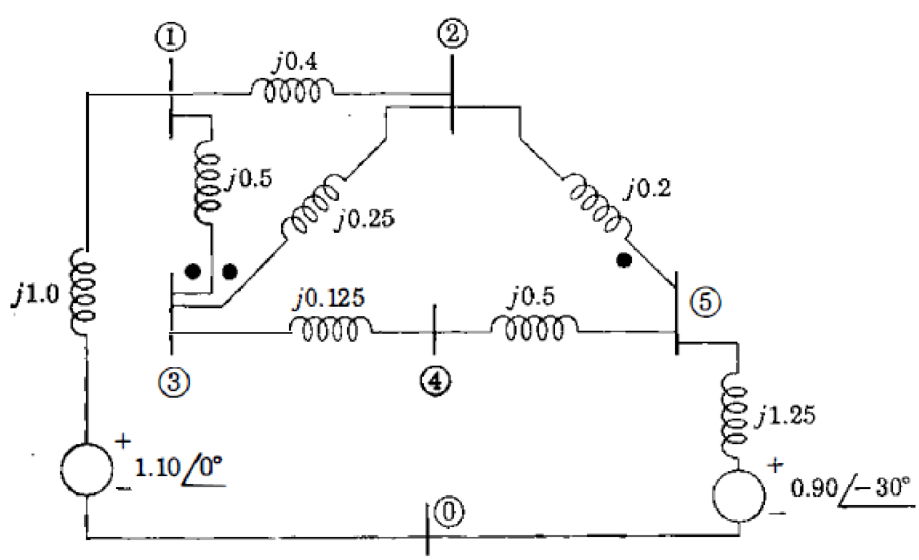
Answer all Questions. Each question carries 5 marks

1. How Z_{BUS} matrix be modified, if any line is removed from the existing network?
2. Explain three phase load flow. Write the equations for three phase AC/DC load flow.
3. Discuss the use of Z_{BUS} in the analysis of unsymmetrical fault.
4. Explain the causes for contingencies and the need for contingency analysis for power systems.
5. Explain how bad data is detected and identified.

PART B

Answer any five Questions. Each Question carry 7 marks

6. Determine the Y_{BUS} for the following power system. Values shown are voltages and impedances in per unit. Consider the lines 1 – 3 and 2 – 3 are mutually coupled as indicated by the dots beside them and their mutual impedance is j 0.15 per unit.



7. Enumerate the procedures involved in the AC-DC load flow with necessary mathematical expressions.

8. For a power system the admittance and impedance matrices for the fault studies are as follows. The pre-fault voltages are 1.0 pu at all the buses. The system was unloaded prior to the fault. A solid 3-phase fault takes place at bus 2. Find the per unit fault feeds from generators connected to buses 1 and 2 and the post fault voltages at buses 1 and 3 in per unit.

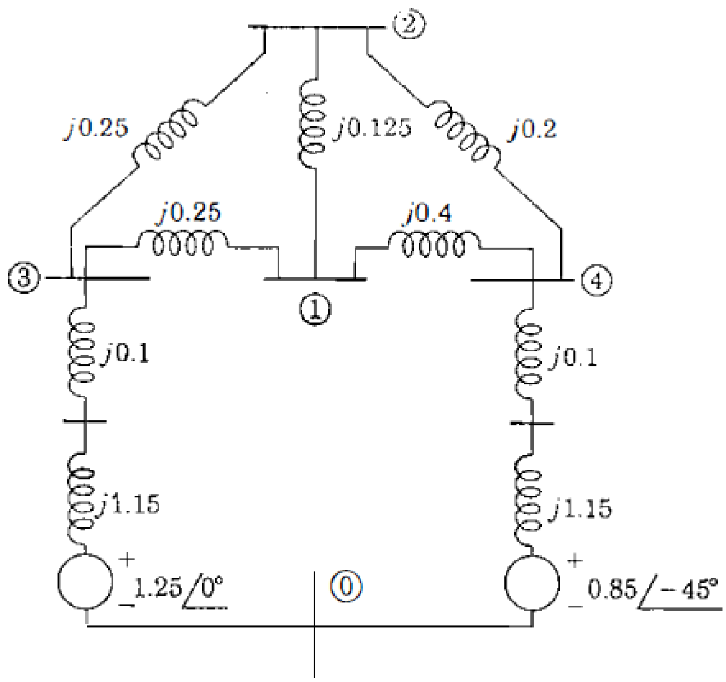
$$Y_{bus} = \begin{bmatrix} -j8.75 & j1.25 & j2.50 \\ j1.25 & -j6.25 & j2.50 \\ j2.50 & -j2.50 & -j5.00 \end{bmatrix} \qquad Z_{bus} = \begin{bmatrix} j0.16 & j0.08 & j0.12 \\ j0.08 & j0.24 & j0.16 \\ j0.12 & j0.16 & j0.34 \end{bmatrix}$$

9. Explain the method of state estimation by orthogonal decomposition algorithm.

10. Describe the analysis of single contingency using network sensitivity factors.

11. Discuss the structure and formation of H_x matrix.

12. For the power system shown in figure, lines are represented by their series reactance. Using distribution factors, predict the current in line 2 - 3 when the line 1 - 4 is outaged under the given operating conditions.



EE3

No.	Syllabus
1	**Network Model (8 hours)**
	Admittance model - Branch and Node admittances, Y_{BUS} with mutually coupled branches, Modification of Y_{BUS} - branch addition and removal. **Impedance model** - Thevenin's theorem and Z_{BUS}, Algorithms for building Z_{BUS}. Modification of existing Z_{BUS}, Mutually coupled branches in Z_{BUS}.
2	**AC-DC Load Flow (8 hours)**
	Load flow using Newton Raphson method – qualitative and quantitative analysis (upto 3 buses), FDLF, DC load flow, Introduction to Three-phase Load flow. DC system model, AC-DC Load flow - Single phase algorithm, Problem formulation, Sequential solution techniques.
3	**Fault Analysis (8 hours)**
	Symmetrical faults - Fault calculations using Z_{BUS}, Fault calculations using Z_{BUS} equivalent circuits, Unsymmetrical faults on Power Systems - Fault calculations using Z_{BUS}
4	**Contingency Analysis (8 hours)**
	Z_{BUS} method in Contingency Analysis, Network sensitivity factors, Analysis of Single Contingencies and Multiple Contingencies, Contingency analysis by DC model.
5	**State Estimation (8 hours)**
	State Estimation - Method of weighted least squares, Test for bad data, Power System State Estimation, Structure and formation of H_x matrix, Line Power flow state estimator, State estimation by orthogonal decomposition, Network observability and pseudo measurements.

EE3

Course Plan

No	Topic	No. of Lectures
1	**Network Model**	
1.1	Admittance model - Branch and Node admittances, Mutually coupled branches in Y_{BUS} , Modification of Y_{BUS} - addition and removal of branches.	2
1.2	Impedance model - Thevenin's theorem and Z_{BUS},	1
1.3	Algorithms for building Z_{BUS}	2
1.4	Modification of existing Z_{BUS}, Mutually coupled branches in Z_{BUS}	3
2	**AC-DC Load Flow**	
2.1	Load flow using Newton Raphson method – qualitative and quantitative analysis (upto 3 buses),	2
2.2	FDLF, DC load flow	1
2.3	Introduction to Three-phase Load flow, DC system model	2
2.4	AC-DC Load flow - Single phase algorithm, Problem formulation, Sequential solution techniques	3
3	**Fault Analysis**	
3.1	Symmetrical faults	1
3.2	Fault calculations using Z_{BUS}	2
3.3	Fault calculations using Z_{BUS} equivalent circuits	2
3.4	Unsymmetrical faults on Power Systems	1
3.5	Fault calculations using Z_{BUS}	2
4	**Contingency Analysis**	
4.1	Z_{BUS} method in Contingency Analysis, Network sensitivity factors	2
4.2	Analysis of Single Contingencies	2
4.3	Analysis of Multiple Contingencies	2
4.3	Contingency analysis by DC model	2
5	**State Estimation**	
5.1	State Estimation - Method of weighted least squares, Test for bad data	3

5.2	Power System State Estimation, Structure and formation of H_x matrix	2
5.3	Line Power flow state estimator, State estimation by orthogonal decomposition, Network observability and pseudo measurements	3

Text Books

1. John J. Grainger, William D. Stevenson, Jr., Power System Analysis, Tata McGraw-Hill, 2017.

2. J. Arriliga and N.R. Watson, Computer Modelling of Electrical Power Systems, 2/e, John Wiley, 2001.

3. Stagg and E. l. Abiad, Computer Methods in Power System Analysis, McGraw Hill, 1968.

Reference Books

1. Allen J Wood, Bruce F Wollenberg, Gerald B. Sheble, Power Generation Operation and Control, 3rd Edn, Wiley.

2. George Kusic, Computer Aided Power System Analysis, CRC Press, 2018.

3. Arthur R. Bergen, Vijay Vittal, Power Systems Analysis (English) 2nd Edition, Pearson Higher Education.

4. Power System Analysis and Design by J. Duncan Glover and M.S. Sarma., Cengage 3rd Edition.

EE3

221EEE013	DESIGN OF RENEWABLE ENERGY SYSTEMS	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 1	3	0	0	3

Preamble: The course aims to design and evaluate renewable energy systems for stand-alone and grid-integrated operation.

Prerequisites: Nil

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

CO 1	Understand the fundamental principles governing solar photovoltaic power generation.
CO 2	Design PV systems for off-grid applications
CO 3	Design PV systems for grid connected applications
CO 4	Design power generation systems based on wind energy conversion principle
CO 5	Design small hydro power systems and energy storage systems

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

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

End Semester Examination Pattern:

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

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

Model Question paper

QP CODE: **PAGES: 2**

Reg No:_______________ **Name:_________________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 221EEE013

Course Name: Design of Renewable Energy Systems

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

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

1) Explain the effect of cell mismatch and shadowing on the operation of a solar PV module.

2) Elucidate the effect of Irradiance and Cell Temperature on the operation of a PV system.

3) Choose one among Perturb and Observe method (P&O) and Incremental Conductance method for maximum power point tracking of solar PV systems for rapidly varying solar insolation condition. Justify the selection.

4) Prove that theoretical power fraction that can be extracted from an ideal wind stream is 0.593.

5) Consider a reaction turbine running at 600 rpm, which has an external diameter and a width of 600 mm and 200 mm, respectively. The absolute velocity of water at inlet is equal to 30 m/s and the guide vanes are at 25° to the wheel tangent. Obtain discharge through the turbine and inlet vane angle.

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

6)

i. A solar cell of area 12 cm2 illuminated uniformly with solar power of $100 mW/cm^2$ has a fill factor of 0.7. Open circuit voltage V_{OC}=1.5 V and the short circuit current I_{SC}= 250mA. Obtain the maximum efficiency (%) of the cell. **(3)**

ii. Comment on the importance of blocking diodes and by-pass diodes in the operation of a PV array. **(4)**

7) A PV system feeds a dc motor to produce 1 hp power at the shaft. The motor efficiency is 85%. Each module has 36 multicrystalline silicon solar cells arranged in 9 × 4 matrix. The cell size is 125mm × 125mm and cell efficiency is 12%. Calculate the number of modules required in the PV array. Assume global radiation incident normally to the panel as $1 kW/m^2$.

8) A house has the following electrical appliance usage: Four 18-W fluorescent lamps with electronic ballast used 4 h/day. Two 60-W fans used for 2 h/day. One 75-W refrigerator that runs 24 h/day with the compressor run 12 h and off 12 h. The system will be powered by a 12 Vdc, 110 Wp PV module.

i) Determine power consumption demands
ii) Rating of the PV panel
iii) Rating of Inverter
iv) Rating of battery
v) Rating of Solar Charge controller **(7)**

9)

i. With the help of a diagram explain the operation of variable-speed wind turbine with synchronous generator **(4)**

ii. Calculate the number of wind turbines needed to install a 200 MW wind farm in a site with air density of 1.225 Kg/m^3, average wind speed 9 m/s at height 10 m and 1/7 friction coefficient for day. Use a wind turbine that has a hub height of 80 m with 44 m blade length and 0.32 power coefficient. **(3)**

10)

i. Calculate the output voltage and capacity of a 12 V and 18 Ah cell, with 5S6P arrangement. **(3)**

ii. Explain the working principle of flywheel energy storage systems. Comment on the important sub-systems involved. **(4)**

11) Elucidate the important considerations during grid integration of PV systems with reference to IEEE 1547. (7)

12)

i. With a neat diagram explain solar irradiation measurement using Pyranometer. **(3)**

ii. Draw the Wind Turbine Power Characteristic Curve and explain the regions of operation. **(4)**

EE3

Syllabus

No	Topic	No. of Lectures
1	**Present status of renewable energy technology, Fundamentals of Solar PV** Scientific principles of renewable energy, Technical and Social implications; World Energy Scenario; Indian Energy Scenario; International Solar Alliance-Scope of operation; Global Wind Energy Council India-Scope of operation Trends in Solar PV Technologies; Physical Characteristics- Monocrystalline Silicon Cell- Polycrystalline Silicon Cell; Semiconductor Technology-PV Cell-Equivalent Circuit- Electrical Characteristics- Short Circuit Current - Open Circuit Voltage - Fill Factor - Efficiency -Module-String-Array; Cell Mismatch in a Module, Effect of shadowing; Principles of bypass diodes and blocking diodes, PV Components and Standards Fundamentals of Solar Radiation- Sun Earth angles; Relevance of Solar Resources Assessment in Solar PV Plant Implementation; Solar Radiation Measurement Instruments-Pyranometer, Pyrheliometer; GIS Mapping of Solar Resource Potential	8
2	**PV System Design for Off-Grid Applications** Types of Solar PV Systems-Standalone-grid connected-hybrid (Introduction only), Guidelines for Designing of Stand-Alone Solar PV Systems-Planning and site survey- Assessment of energy requirement- Assessment of solar resource availability- System concept development- Sizing of main component of the PV systems- Selection of components of the PV system. Guidelines for selection of PV Modules, battery, Inverter, Protection devices. Factors Affecting PV System Performance- Irradiance- Cell Temperature-Solar Altitude and Solar Spectrum	8
3	**Design of Grid-connected PV system** Components of Grid connected PV system; Interface Requirements- IEEE 1547 -voltage-frequency-power quality-islanding Design of a PV Grid-Connected System- power and energy estimates-PV module sizing-PV array sizing-Inverter sizing-battery sizing-charge controller sizing - Numerical problems Grid connection principle, PV to grid topologies, 3ph d-q controlled grid connection, dq-axis theory, AC to DC transformations, DC to AC transformations, Complete 3ph grid connection, 1ph d-q controlled grid connection Inverter topologies in photovoltaic application Control of grid connected PV systems - Renewable side controllers - MPPT control ; Grid-side controllers - Active and reactive power control MPPT techniques for Solar PV- P & O algorithm, Incremental Conductance method- Temperature method	8
4	**Design of Wind energy conversion system** Wind Data Analysis and Resource Estimation; Wind Measurement and Instrumentation; Wind Turbine Technology- Classification-based on axis of rotation-components Wind Power Calculation- Wind Turbine Power Characteristic Curve-Stall control-Pitch angle Control-Tip speed ratio Types of wind energy conversion systems- Type 1- Type 2- Type 3- Type-4, Type-5. Variable-speed Operation of Synchronous Generators, Variable-speed	8

	Operation of Squirrel Cage Induction Generators, Variable-speed Operation with Wound Rotor Induction Generators, Power Curve Prediction Design Procedure-Determine application-Review previous experience-Select topology-Estimate preliminary loads- Develop tentative design-Predict performance-Evaluate design-Estimate costs and cost of energy-Refine design-Build prototype-Test prototype-Design production machine Grid-connected Turbine Operation Constant-speed Operating Schemes- Stall-regulated Turbines, Two-speed, Stall-regulated Turbines, Active Pitch-regulated Turbines Variable-speed Operating Schemes- Stall-regulated Turbines, Active Pitch-regulated Turbines, Small-range Variable-speed Turbines	
5	**Design of Small Hydro Power Systems and Energy storage systems** Design of Small Hydro Power Systems- Head Measurement- Flow Measurement- Design of an Appropriate Turbine for Small Hydro Power Systems Projects Economic Analysis Of Small Hydro Power Plant Projects- Investment Costs-Annual Costs- Costs for Kaplan Turbines-Francis Turbines and Pelton Turbines- Cost Analysis for Run-of-River Small Hydro Power Systems Projects The importance of energy storage and distribution; Small-Scale Electrical Energy Storage Systems-Batteries-Self discharge rate- discharge rate- State of Charge Important Consideration in the Batteries' Design- Bank voltage- Bank capacity Large-Scale Electrical Energy Storage Systems- Flywheel- Energy Storage Capacity- Principles of Energy Conversion- Energy Losses- Flywheel Subsystems	8

EE3

Course Plan

No	Topic	No. of Lectures
1	**Present status of renewable energy technology, Fundamentals of Solar PV**	
1.1	Scientific principles of renewable energy, Technical and Social implications; World Energy Scenario; Indian Energy Scenario; International Solar Alliance-Scope of operation; Global Wind Energy Council India-Scope of operation	2
1.2	Trends in Solar PV Technologies; Physical Characteristics- Monocrystalline Silicon Cell- Polycrystalline Silicon Cell; Semiconductor Technology-PV Cell-Equivalent Circuit- Electrical Characteristics- Short Circuit Current - Open Circuit Voltage -	2
1.3	Fill Factor - Efficiency -Module-String-Array; Cell Mismatch in a Module, Effect of shadowing; Principles of bypass diodes and blocking diodes, PV Components and Standards	2
1.4	Fundamentals of Solar Radiation- Sun Earth angles; Relevance of Solar Resources Assessment in Solar PV Plant Implementation; Solar Radiation Measurement Instruments- Pyranometer, Pyrheliometer; GIS Mapping of Solar Resource Potential	2
2	**PV System Design for Off-Grid Applications**	
2.1	Types of Solar PV Systems-Standalone-grid connected-hybrid (Introduction only), Guidelines for Designing of Stand-Alone Solar PV Systems- Planning and site survey	2
2.2	Assessment of energy requirement- Assessment of solar resource availability- System concept development- Sizing of main component of the PV systems- Selection of components of the PV system.	2
2.3	Guidelines for selection of PV Modules, battery, Inverter, Protection devices.	3
2.4	Factors Affecting PV System Performance- Irradiance- Cell Temperature- Solar Altitude and Solar Spectrum	1
3	**Design of Grid-connected PV system**	
3.1	Components of Grid connected PV system; Interface Requirements- IEEE 1547 -voltage-frequency-power quality-islanding	1
3.2	Design of a PV Grid-Connected System- power and energy estimates-PV module sizing-PV array sizing-Inverter sizing-battery sizing-charge controller sizing - Numerical problems	2
3.3	Grid connection principle, PV to grid topologies, 3ph d-q controlled grid connection, dq-axis theory, AC to DC transformations, DC to AC transformations, Complete 3ph grid connection, 1ph d-q controlled grid connection	2
3.4	Inverter topologies in photovoltaic application Control of grid connected PV systems - Renewable side controllers - MPPT control; Grid-side controllers - Active and reactive power control MPPT techniques for Solar PV- P & O algorithm, Incremental Conductance method- Temperature method	3
4	**Design of Wind energy conversion system**	
4.1	Wind Data Analysis and Resource Estimation; Wind Measurement and Instrumentation; Wind Turbine Technology- Classification-based on axis of rotation-components Wind Power Calculation- Wind Turbine Power Characteristic Curve-Stall Control-Pitch angle Control-Tip speed ratio	2
4.2	Types of wind energy conversion systems- Type 1- Type 2- Type 3- Type-4, Type-5. Variable-speed Operation of Synchronous Generators, Variable-speed Operation of Squirrel Cage Induction Generators, Variable-speed Operation with Wound Rotor Induction Generators, Power Curve Prediction	2
4.2	Design Procedure-Determine Application-Review previous experience- Select Topology-Estimate preliminary loads- Develop tentative design-	1

	Predict Performance-Evaluate Design-Estimate costs and cost of energy-Refine Design-Build Prototype-Test Prototype-Design production machine	
4.3	Grid-connected Turbine Operation Constant-speed Operating Schemes- Stall-regulated Turbines, Two-speed, Stall-regulated Turbines, Active Pitch-regulated Turbines Variable-speed Operating Schemes- Stall-regulated Turbines, Active Pitch-regulated Turbines, Small-range Variable-speed Turbines	3
5	**Design of Small Hydro Power Systems and Energy storage systems**	
5.1	Design of Small Hydro Power Systems- Head Measurement- Flow Measurement- Design of an Appropriate Turbine for Small Hydro Power Systems Projects	2
5.2	Economic Analysis of Small Hydro Power Plant Projects- Investment Costs-Annual Costs- Costs for Kaplan Turbines-Francis Turbines and Pelton Turbines- Cost Analysis for Run-of-River Small Hydro Power Systems Projects	3
5.3	The importance of energy storage and distribution; Small-Scale Electrical Energy Storage Systems-Batteries-Self discharge rate- discharge rate- State of Charge Important Consideration in the Batteries' Design- Bank voltage- Bank capacity Large-Scale Electrical Energy Storage Systems- Flywheel- Energy Storage Capacity- Principles of Energy Conversion- Energy Losses- Flywheel Subsystems	3

Text Books

1. P. Mohanty , T. Muneer, M. Kolhe, Solar Photovoltaic System Applications A Guidebook for Off-Grid Electrification, Springer
2. G.N. Tiwari: Solar Energy-Fundamentals, Design, Modelling and Applications, Narosa Publishers, 2002

Reference Books

1. A Anzalchi, A Sarwat, Overview of Technical Specifications for Grid-Connected Photovoltaic Systems, Energy Conversion and Management, Volume 152, 2017, Pages 312-327
2. G.B. Gharehpetian, S. Mohammad Mousavi Agah, Distributed Generation Systems Design, Operation and Grid Integration, Butterworth-Heinemann, 2017
3. J. F. Manwell, J. G. McGowan and A. L. Rogers, Wind Energy Explained Theory, Design and Application Second Edition, John Wiley & Sons Ltd
4. Yaramasu, Venkata & Wu, Bin & Sen, Paresh & Kouro, Samir & Narimani, Mehdi. (2015). High-Power Wind Energy Conversion Systems: State-of-the-Art and Emerging Technologies. Proceedings of the IEEE. 103. 740 - 788. 10.1109/JPROC.2014.2378692
5. Mukund R. Patel, Wind and Solar Power Systems, CRC Press
6. J.Twidell, T. Weir, Renewable Energy Sources, , 2nd edition , Taylor and Francis.
7. B H Khan - Non Conventional Energy Resources-Mc Graw Hill India (2016)
8. NPTEL Course on Design of photovoltaic systems, L Umanand
9. Chenming, H. and White, R.M., Solar Cells from B to Advanced Systems, McGraw Hill Book Co, 1983
10. Ruschenbach, HS, Solar Cell Array Design Hand Varmostrand, Reinhold, NY, 1980
11. Proceedings of IEEE Photovoltaics Specialists Conferences, Solar Energy Journal.

EE3

221EEE014	SMART GRID TECHNOLOGIES AND APPLICATION	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 1	3	0	0	3

Preamble: This course mainly focuses on fundamentals of smart grid for its implementation in the existing power system network. This course provides an overview of the smart grid and its components. It also provides detailed analysis in terms of energy management, distribution management, communication and networking for smart grid implementation.

Prerequisites: Nil

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

CO 1	Explain the basic concept of smart grid.
CO 2	Elaborate the various infrastructure and technologies for substation and feeder automation.
CO 3	Describe the various functions of distribution management system.
CO 4	Use various tools for modelling and analysing distribution system.
CO 5	Apply the various communication, networking and computing infrastructure for smart metering systems and demand side management.
CO 6	Select various infrastructure and technologies for consumer domain of smart grid.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: **40 marks**

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

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

Test paper, 1 no.: **10 marks**

(Test paper shall include minimum 80% of the syllabus.)

End Semester Examination Pattern:

End Semester Examination: **60 marks**

The end semester examination will be conducted by the respective College. There will be two parts; **Part A** and **Part B**.

EE3

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

Model Question Paper

QP CODE: **PAGES: 2**

Reg. No.:……………. **Name:……………………..**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 221EEE014

Course Name: Smart Grid Technologies and Applications

Max. Marks: 60 Duration: 2.5 Hours

Part A (Answer ALL Questions. Each question carries 5 marks)

1.	Define smart grid and give its functions. Elaborate the present developments on the smart grid implementation in India.	(5)
2.	Write notes on Intelligent Electronic Devices (IED). Discuss their application for monitoring and protection of power system.	(5)
3.	Elaborate on how the advances in communication technologies can improve the volt/VAR control in smart grid.	(5)
4.	(a) Discuss the significance of smart appliances in smart grid.	(3)
	(b) Write a note on "Real time prizing".	(2)
5.	What is cloud computing? Classify cloud computing based on (i) Cloud computing deployment (ii) Cloud computing Service.	

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

6.	Explain the need of smart grid. List the various opportunities and challenges in smart grid implementation.	(7)
7.	Discuss WAMS and PMUs with the help of a schematic. Elaborate how reliability of the system can be improved by its implementation.	(7)
8.	Explain the need for adopting common standard for substation automation. Explain various features of IEC 61850.	(7)
9.	Explain how distribution automation can enhance the reliability of distribution system.	(7)
10.	Discuss the functions of the smart meter with the help of a schematic. Discuss the various benefits and challenges in the deployment of smart meters.	(7)
11.	List the various load shaping strategies. Discuss in detail the strategies that can be adopted by residential consumers.	(7)
12.	Discuss the various communication technologies used in Home Area Network (HAN).	(7)

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Syllabus

No	Topic	No. of Lectures
1	**Introduction to Smart Grid** Evolution of Electric Grid, Concept of Smart Grid, Definitions Need of Smart Grid, Functions of Smart Grid, Opportunities & Barriers of Smart Grid, Difference between conventional & smart grid Concept of Resilient & Self-Healing Grid, Present development & International policies on Smart Grid. Case study of Smart Grid.	8
2	**Energy Management System (EMS)** Smart substations - Substation Automation, Feeder Automation, SCADA, Smart Switchgear, Remote Terminal Unit, Intelligent Electronic Devices & their application for monitoring & protection, IEC 61850 Wide area monitoring, Phasor Measurement Unit, protection and control Smart Integration of Energy Resources – Renewable, Intermittent Power Sources – Energy Storage, Impact of Plug-In Electric Vehicles	8
3	**Distribution Management System (DMS)** Volt / VAR control, Fault Detection, Isolation and Service Restoration, Network Reconfiguration Fault Current Limiting, Shunt Compensation (D-STATCOM, Active Filtering, Shunt Compensator With Energy Storage), Series Compensation Outage Management System, Customer Information System, Geographical Information System Modelling And Analysis Tools - Distribution System Modelling, Topology Analysis, Load Forecasting, Power Flow Analysis, Fault Calculations, State Estimation, Other Analysis Tools	8
4	**Smart Metering and Demand-Side Integration** Evolution of Electricity Metering, Smart Meters, Smart Appliances, Smart Sensors, Home & Building Automation Advanced Metering Infrastructure (AMI), AMI Protocols – Standards and Initiatives Demand Side Management and Demand Response Programs, Demand Pricing and Time of Use, Real Time Pricing, Peak Time Pricing - Problems	8
5	**Communication, Networking and Interfacing** Architectures, standards, PLC, Zigbee, GSM, Local Area Network (LAN) - Home Area Network (HAN) - Wide Area Network (WAN) - Broadband over Power line (BPL) - IP based Protocols Basics of Web Service and CLOUD Computing, Cyber Security for Smart Grid Applications of smart grid to power systems and case study	8

EE3

Course Plan

No	Topic	No. of Lectures
1	**Introduction to Smart Grid**	
1.1	Evolution of Electric Grid, Concept of Smart Grid, Definitions	2
1.2	Need of Smart Grid, Functions of Smart Grid, Opportunities & Barriers of Smart Grid, Difference between conventional & smart grid	3
1.3	Concept of Resilient & Self-Healing Grid, Present development & International policies on Smart Grid. Case study of Smart Grid.	3
2	**Energy Management System (EMS)**	
2.1	Smart substations - Substation Automation, Feeder Automation, SCADA, Smart Switchgear, Remote Terminal Unit, Intelligent Electronic Devices & their application for monitoring & protection, IEC 61850	3
2.2	Wide area monitoring, Phasor Measurement Unit, protection and control	2
2.3	Smart Integration of Energy Resources – Renewable, Intermittent Power Sources – Energy Storage, Impact of Plug-In Electric Vehicles	3
3	**Distribution Management System (DMS)**	
3.1	Volt / VAR control, Fault Detection, Isolation and Service Restoration, Network Reconfiguration	2
3.2	Fault Current Limiting, Shunt Compensation (D-STATCOM, Active Filtering, Shunt Compensator with Energy Storage), Series Compensation	2
3.3	Outage Management System, Customer Information System, Geographical Information System	1
3.4	Modelling And Analysis Tools - Distribution System Modelling, Topology Analysis, Load Forecasting, Power Flow Analysis, Fault Calculations, State Estimation, Other Analysis Tools	3
4	**Smart Metering and Demand-Side Integration**	
4.1	Evolution of Electricity Metering, Smart Meters, Smart Appliances, Smart Sensors, Home & Building Automation	2
4.2	Advanced Metering Infrastructure (AMI), AMI Protocols – Standards And Initiatives	3
4.3	Demand Side Management And Demand Response Programs, Demand Pricing And Time Of Use, Real Time Pricing, Peak Time Pricing - Problems	3
5	**Communication, Networking and Interfacing**	
5.1	Architectures, standards, PLC, Zigbee, GSM, Local Area Network (LAN) - Home Area Network (HAN) - Wide Area Network (WAN) - Broadband over Power line (BPL) - IP based Protocols	4
5.2	Basics of Web Service and CLOUD Computing, Cyber Security for Smart Grid.	2
5.3	Applications of smart grid to power systems and case study	2

Text Books

1. James Momoh, “Smart Grid: Fundamentals of design and analysis”, John Wiley & sons Inc, IEEE press 2012.

Reference Books

1. Stuart Borlase ‘Smart Grid: Infrastructure, Technology and Solutions’, CRC Press 2012.
2. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, ‘Smart Grid: Technology and Applications’, Wiley, 2012.
3. Mini S. Thomas, John D McDonald, ‘Power System SCADA and Smart Grids’, CRC Press, 2015
4. Kenneth C. Budka, Jayant G. Deshpande, Marina Thottan, ‘Communication Networks for Smart Grids’, Springer, 2014.
5. Fereidoon P. Sioshansi, “Smart Grid: Integrating Renewable, Distributed & EfficientEnergy”, Academic Press, 2012.

6. Clark W. Gellings, “The smart grid: Enabling energy efficiency and demand response”, Fairmont Press Inc, 2009.
7. Ali Keyhani, Mohammad N. Marwali, Min Dai “Integration of Green and Renewable Energy in Electric Power Systems”, Wiley

EE3

221EEE015	DESIGN AND ANALYSIS OF MICROGRIDS	CATEGORY	L	T	P	CREDIT
		Program Elective 1	3	0	0	3

Preamble: The course details the fundamental concepts of microgrid and its components, types of microgrids, advantages of microgrid compared to the central conventional grid. Particularly, the course describes general concepts and application, control strategies, protection principles and energy management in microgrids.

Prerequisites: Nil

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

CO 1	Elaborate on the basic structure and principles of microgrid
CO 2	Describe the concepts of integrating distributed generation to microgrid
CO 3	Analyse the operation of microgrid
CO 4	Analyse the principles of protection of the microgrid
CO 5	Explain the concepts of monitoring and energy management of the microgrid

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

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

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

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

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B.

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

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

Model Question paper

QP CODE: **PAGES:1**

Reg No:_______________ **Name:________________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 221EEE015

Course name: DESIGN AND ANALYSIS OF MICROGRIDS

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

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

1) Elucidate the hierarchical control of a microgrid.
2) Explain the need for IEEE 1547 standards.
3) Illustrate how microgrid can be controlled during grid connection and grid separation.
4) Compare different methods of fault current limitation in microgrid.
5) Analyse how power balance can be achieved during grid-connected mode of operation.

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

6) Explain the structure of three-layer microgrid control scheme. **(7)**

7) Elaborate on the hardware components of SCADA in microgrid. **(7)**

8) Analyse how dynamic under-frequency load shedding control can be realised**. (7)**

9) Explain briefly:

- **i.** The need for adaptive protection for microgrid. **(4)**
- **ii.** Protection issues of stand-alone microgrid. **(3)**

10) Explain the major design considerations for microgrid monitoring system. **(7)**

11) Explain Master–slave mode, Peer-to-peer mode control of microgrid. **(7)**

12) 12)

- **i.** Elaborate the major considerations in optimising control of PV power. **(4)**
- **ii.** Comment on the impact of DG integration on power quality and reliability. **(3)**

EE3

Syllabus

No	Topic	No. of Lectures
1	**Composition of the microgrid**	
	Composition of Microgrid –Introduction to a typical Microgrid configuration Structure of Microgrid- Distribution network dispatch layer- Centralized control layer- Local control layer; Operation Modes- Grid-connected operation- Islanded operation (basic principle only); Control Modes: Microgrid control modes- Master–slave mode, Peer-to-peer mode, Combined mode Control architectures in microgrid – Master slave with power-based control, Hierarchical control with centralized and distributed control Classification- By function demand- By capacity- By AC/DC type Technical and economical advantages of Microgrid, Challenges and disadvantages of Microgrid development, Management and operational issues of a Microgrid	8
2	**Microgrid and distributed generation**	
	Need for integration of distributed generation- DER technologies: Combined heat and power (CHP) systems- Wind energy conversion systems (WECS) Solar photovoltaic (PV) systems-Small-scale hydroelectric generation- Storage devices. (principle of operation classification, advantages, disadvantages only) - Interconnection standards IEEE 1547 series SCADA in Microgrids: Hardware components- Remote terminal unit Programmable logic controller- Master station and HMI computers- SCADA communication infrastructure Impact of DG integration on power quality and reliability- Simple standby generation scheme - Secondary DG system with power quality Support- Primary DG system with power quality support to priority loads- Soft grid-connected DG with power quality support to priority loads	8
3	**Control and operation of the microgrid**	
	Three-State Control of Independent Microgrid- Steady-state constant-frequency and constant-voltage control- Dynamic generator tripping and load shedding control- Transient fault protection Inverter Control- Grid-Tie Inverter Control- Power Converter System Control Grid Connection And Separation Control-- Grid Connection Control- Grid Separation Control Operation- Grid-connected operation- Islanded operation	8
4	**Protection of the microgrid**	
	Challenges for Microgrid Protection- Distribution System Protection - Over-Current Distribution Feeder Protection - Over-Current Distribution Feeder Protection and DERs- Grid Connected Mode with External Faults - Grid Connected Mode with Fault in the Microgrid -Grid Connected Mode with Fault at the End-Consumer Site - Islanded Mode with Fault in the Microgrid- Islanded Mode and Fault at the End-Consumer Site Adaptive Protection for Microgrids-Adaptive Protection Based on Pre-Calculated Settings -Microgrid with DER Switched off, in Grid-Connected Mode -Microgrid with Synchronous DERs Switched on in Grid Connected and Islanded Modes - Adaptive Protection System Based on Real-Time Calculated Settings- Communication Architectures and Protocols for Adaptive Protection Fault Current Source for Effective Protection in Islanded Operation; Fault Current Limitation in Microgrids; Protection issues of stand-alone Microgrid-Protection of microsources- NEC requirements for distribution transformer protection- Neutral grounding requirements	8

5	**Monitoring and energy management of the microgrid**	
	Structure of the monitoring system Composition of the monitoring system- PV monitoring- Wind power monitoring- Microturbine monitoring- ES monitoring- Load monitoring Design of the monitoring system ENERGY MANAGEMENT- Forecast of DG- Load forecast- Frequency response characteristics of DG and loads- Power balance OPTIMIZED CONTROL- Optimized control of PV power- Optimized control of wind power- Optimized control of various types of ESs- Optimized dispatch strategies	8

Course Plan

No	Topic	No. of Lectures
1	**Composition of the microgrid**	
1.1	Composition of Microgrid –Introduction to a typical Microgrid configuration	1
1.2	Structure of Microgrid- Distribution network dispatch layer- Centralized control layer- Local control layer; Operation Modes- Grid-connected operation- Islanded operation (basic principle only);	2
1.3	Control Modes: Microgrid control modes- Master–slave mode, Peer-to-peer mode, Combined mode Control architectures in microgrid – Master slave with power-based control, Hierarchical control with centralized and distributed control	2
1.4	Classification- By function demand- By capacity- By AC/DC type	1
1.5	Technical and economical advantages of Microgrid, Challenges and disadvantages of Microgrid development, Management and operational issues of a Microgrid	2
2	**Microgrid and distributed generation**	
2.1	Need for integration of distributed generation- DER technologies: Combined heat and power (CHP) systems- Wind energy conversion systems (WECS)	2
2.2	Solar photovoltaic (PV) systems-Small-scale hydroelectric generation- Storage devices. (principle of operation classification, advantages, disadvantages only) Interconnection standards IEEE 1547 series	2
2.3	SCADA in Microgrids: Hardware components- Remote terminal unit Programmable logic controller- Master station and HMI computers- SCADA communication infrastructure	2
2.4	Impact of DG integration on power quality and reliability- Simple standby generation scheme - Secondary DG system with power quality Support- Primary DG system with power quality support to priority loads- Soft grid-connected DG with power quality support to priority loads	2
3	**Control and operation of the microgrid**	
3.1	Three-State Control of Independent Microgrid- Steady-state constant-frequency and constant-voltage control- Dynamic generator tripping and load shedding control- Transient fault protection	3
3.2	Inverter Control- Grid-Tie Inverter Control- Power Converter System Control Grid Connection And Separation Control-- Grid Connection Control- Grid Separation Control	3
3.3	Operation- Grid-connected operation- Islanded operation	2
4	**Protection of the microgrid**	
4.1	Challenges for Microgrid Protection- Distribution System Protection - Over-	3

	Current Distribution Feeder Protection - Over-Current Distribution Feeder Protection and DERs- Grid Connected Mode with External Faults - Grid Connected Mode with Fault in the Microgrid -Grid Connected Mode with Fault at the End-Consumer Site - Islanded Mode with Fault in the Microgrid-Islanded Mode and Fault at the End-Consumer Site	
4.2	Adaptive Protection for Microgrids-Adaptive Protection Based on Pre-Calculated Settings -Microgrid with DER Switched off, in Grid-Connected Mode -Microgrid with Synchronous DERs Switched on in Grid Connected and Islanded Modes - Adaptive Protection System Based on Real-Time Calculated Settings- Communication Architectures and Protocols for Adaptive Protection	3
4.3	Fault Current Source for Effective Protection in Islanded Operation; Fault Current Limitation in Micrograids; Protection issues of stand-alone Microgrid-Protection of microsources- NEC requirements for distribution transformer protection- Neutral grounding requirements	2
5	**Monitoring and energy management of the microgrid**	
5.1	Structure of the monitoring system Composition of the monitoring system- PV monitoring- Wind power monitoring- Microturbine monitoring- ES monitoring- Load monitoring Design of the monitoring system-	2
5.2	ENERGY MANAGEMENT- Forecast of DG- Load forecast- Frequency response characteristics of DG and loads- Power balance	3
5.3	OPTIMIZED CONTROL- Optimized control of PV power- Optimized control of wind power- Optimized control of various types of ESs- Optimized dispatch strategies	3

Text Books

1. S. Chowdhury, S.P. Chowdhury and P. Crossley, Microgrids and Active Distribution Networks, The Institution of Engineering and Technology

Reference Books

1. Li Fusheng, Li Ruisheng, Zhou Fengquan, Microgrid Technology and Engineering Application, Academic Press
2. N Hatziargyriou, Microgrids Architectures And Control, 2014 John Wiley and Sons Ltd

221EEE016	POWER SYSTEM PLANNING AND RELIABILITY	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 1	3	0	0	3

Preamble: To understand the importance of planning and maintaining reliability of power system components.

Prerequisites: Nil

Course Outcomes:

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

CO 1	Perform long term and short-term planning of generation, transmission and distribution systems
CO 2	Forecast load under sensitive and non-sensitive weather conditions periodically.
CO 3	Optimize generation cost for reliable operation of generating units. Apply reliability model to find out the reliability of an isolated and interconnected generation system.
CO 4	Identify the transmission model for reliability analysis and apply it to the transmission system.
CO 5	Apply different models for network expansion in the transmission system and analyse the different components in distribution planning.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

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

Continuous Internal Evaluation Pattern:

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

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

Test paper, 1 no. : **10 marks**

End Semester Examination Pattern:

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

EE3

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

Model Question paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
FIRST SEMESTER M.TECH DEGREE EXAMINATION, MONTH 20XX
(ELECTRICAL ENGINEERING DEPARTMENT)
(POWER SYSTEMS)
221EEE016 POWER SYSTEM PLANNING AND RELIABILITY

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

Part A

Answer all five questions. Each question carries 5 marks.

1. Define vision, mission and values with respect to power system planning. Explain the concept of Planning Standardization.

2. Give a brief account of the classification of loads. What do you mean by electricity forecasting?

3. What are the different probabilistic generating unit models?

4. Describe LOLP and ε(DNS) with respect to transmission system reliability.

5. Write a note on Tellegen's theorem.

Part B

Answer any five questions. Each question carries 7 marks.

6. Point out the main objectives of power system planning.

7. Write notes on peak demand forecasting and energy forecasting.

8. What is the basic concept of generation system reliability? Explain the purpose of conducting reliability evaluation.

9. How is reliability analysis conducted for interconnected systems?

10. Explain the basic philosophy behind probabilistic transmission system reliability analysis?

11. What are the algorithms used for capacity state classification? Explain any one algorithm in detail?

12. With neat block diagram explain the production costs needed in order to economically evaluate an expansion plan dominated by nuclear generation?

Syllabus

MODULE 1 (8 Hours)

Objectives of system planning: Long term and short term planning-stages in planning -Policy studies - Planning standardization studies- System and Network Reinforcement studies.

MODULE 2 (8 Hours)

Load forecasting : Classification of loads-Forecast methodology- Energy forecasting-Non weather sensitive forecast-Weather sensitive forecast- Total forecast-Annual and monthly peak load forecast.

MODULE 3 (8 Hours)

Generation system cost and reliability analysis – Production costing –Fuel inventories-Energy transaction and off-peak loading. Reliability analysis-Reliability Concepts- Exponential Distribution mean time to failure-Series and Parallel system – Markov Process- Recursive technique- Probability Models for generator unit and loads-Reliability Analysis of isolated and inter connected system.

MODULE 4 (8 Hours)

Transmission system reliability analysis: Transmission system reliability model analysis – Capacity state classification- Average Interruption rate method – LOLP method.

MODULE 5 (8 Hours)

Transmission system Expansion Planning: Tellegen's theorem, Network sensitivity- Network Decision-Problem formulation solution using DC load flow. An overview of distribution system planning

Course Plan

No	Topic	No. of Lectures
1	Fundamentals	
1.1	Objectives of system planning: Long term and short term planning	2
1.2	stages in planning -Policy studies -	3
1.3	Planning standardization studies- System and Network Reinforcement studies	3
2	Load forecasting	
2.1	Classification of loads-Forecast methodology	2
2.2	Energy forecasting-Non weather sensitive forecast-Weather sensitive forecast-- Weather sensitive forecast-	3
2.3	Total forecast-Annual and monthly peak load forecast	3
3	Generation system cost and reliability analysis:	
3.1	Production costing –Fuel inventories-Energy transaction and off-peak loading	2
3.2	Reliability Concepts- Exponential Distribution mean time to failure-Series and Parallel system – Markov Process-	3
3.3	Recursive technique-Probability Models for generator unit and loads- Reliability Analysis of isolated and inter connected system	3
4	Transmission system reliability analysis:	
4.1	Transmission system reliability model analysis	2
4.2	Capacity state classification	3
4.3	Average Interruption rate method – LOLP method	3
5	Transmission system Expansion Planning:	
5.1	Tellegen's theorem - Network sensitivity-	2
5.2	Network Decision - Problem formulation - solution using DC load flow	3
5.3	An overview of distribution system planning	3

EE3

Text Books

1. Reliability Evaluation of Power Systems, Roy Billinton and Ronald N. Allan, Plenum press, New York and London, 1996 Second Edition
2. Reliability Modeling in Electric Power Systems, J. Endrenyi, John Wiley and Sons, 1978, First Edition

Reference Books

1. Sullivan.R.L, Power system planning, McGraw Hill New York 1977.
2. Roy Billinton, “Power System Reliability Evaluation”, Gordon and Breach Science Publishers, Newyork, 1970 Edition.
3. Endreni.J., Reliability modeling in electric power system, John Wiley 2005.
4. Roy Billinton, Ronald N.Allan, “Reliability Evaluation of Engineering Systems”, Pitman Books Limited, London. 1983.

CODE 221EEE017	COURSE NAME FLEXIBLE AC TRANSMISSION SYSTEM	CATEGORY	L	T	P	CREDIT
		Program Elective	3	0	0	3

Preamble:
Advances in Power electronics Industry led to rapid development of Power Electronics controllers for fast real and reactive power control. The aim of the course is to familiarise these advancements to the students.
Prerequisites: Nil

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

CO 1	Identify FACTS devices for various applications in power systems.
CO 2	Analyze single phase and three phase voltage source converters.
CO 3	Compare shunt compensation devices used in FACTS.
CO 4	Analyze series compensation devices used in FACTS.
CO 5	Apply UPFC, IPFC and TCPAR for control of power system.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

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

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

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

Test paper, 1 no. : **10 marks**

Test paper shall include minimum 80% of the syllabus.

EE3

End Semester Examination Pattern:

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

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

Model Question paper

D

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 20XX

ELECTRICAL AND ELECTRONICS ENGINEERING

Streams: POWER SYSTEMS

221EEE017 FLEXIBLE AC TRANSMISSION SYSTEM

Max. Marks: 60 Duration: 2.5 Hours

Part A
Answer ALL Questions

1	Power flow in a transmission line is to be enhanced. Propose a suitable method and justify the same.	(5)
2	Discuss the working of a single-phase inverter.	(5)
3	Compare SVC and STATCOM	(5)
4	Explain the working of GCSC	(5)
5	With the help of a schematic, explain the working of IPFC	(5)

(5x5=25 marks)

Part B
Answer any FIVE full Questions

6	Discuss the analysis of an uncompensated transmission line.	(7)
7	Explain the working of a three-phase voltage source inverter with the help of necessary diagrams.	(7)
8	Analyse the thyristor-controlled reactor used in SVCs	(7)
9	a) Using fundamental equations, prove that series compensation can enhance power flow in a transmission line	(3)
	b) Discuss the working of a SSSC	(4)
10	Explain the control scheme of UPFC for real and reactive power control	(7)
11	Discuss the application of TCPAR	(7)
12	a) Compare the control characteristics of SVC and STATCOM.	(3)
	b) Explain any one method for control of harmonics in inverters	(4)

EE3

Syllabus

No	Topic	No. of Lectures
1	Introduction to FACTS, Power flow in Power Systems, Voltage regulation and reactive power flow control, Classification of FACTS Controllers	8
2	Basic Concept of Voltage-Sourced Converters, Single-Phase Full-Wave Bridge Converter, Three-Phase Full-Wave Bridge Converter, Transformer Connections for 12, 24 and 48-Pulse Operation, Three-Level Voltage-Sourced Converter, Pulse-Width Modulation (PWM) Converter	8
3	Objectives of Shunt Compensation - Static Var Compensators: SVC and STATCOM - Comparison Between STATCOM and SVC	8
4	Objectives of Series Compensation, Variable Impedance Type Series Compensators, Switching Converter Type Series Compensators, Control for Series Reactive Compensators	8
5	Unified Power Flow Controller, Static Voltage and Phase Angle Regulators: TCVR and TCPAR, The Interline Power Flow Controller (IPFC)	8

Course Plan

No	Topic	No. of Lectures
1	**Introduction to FACTS**	
1.1	Power flow in Power Systems – Steady-state and dynamic problems in AC systems	1
1.2	Voltage regulation and reactive power flow control in Power Systems – control of dynamic power unbalances in Power System	1
1.3	Power flow control -Constraints of maximum transmission line loading	1
	Classification of FACTS Controllers - Benefits of FACTS Transmission line compensation	2
1.4	Uncompensated line -shunt compensation - Series compensation - Phase angle control.	2
1.5	Reactive power compensation – shunt and series compensation principles – reactive compensation at transmission and distribution level – Static versus passive VAr Compensators	2
2	**Voltage Source Converters for Static Compensation**	
2.1	Basic Concept of Voltage-Sourced Converters	1
2.2	Single-Phase Full-Wave Bridge Converter Operation - Single Phase-Leg Operation	1
2.3	Square-Wave Voltage Harmonics for a Single-Phase Bridge	1
2.4	Three-Phase Full-Wave Bridge Converter	1
2.5	Transformer Connections for 12, 24 and 48-Pulse Operation	1
2.6	Three-Level Voltage-Sourced Converter: Operation of Three-Level Converter, Fundamental and Harmonic Voltages for a Three-Level Converter	2
2.7	Pulse-Width Modulation (PWM) Converter	1
3	**Static Shunt Compensators: SVC and STATCOM**	
3.1	Objectives of Shunt Compensation	1
3.2	Methods of Controllable Var Generation	2
3.3	Static Var Compensators: SVC and STATCOM	3
3.4	Comparison Between STATCOM and SVC	2
4	**Static Series Compensators**	
4.1	Objectives of Series Compensation	1
4.2	Variable Impedance Type Series Compensators	3
4.3	Switching Converter Type Series Compensators	3
4.4	External (System) Control for Series Reactive Compensators	1
5	**UPFC, Phase angle regulators and IPFC**	
5.1	Unified Power Flow Controller: Circuit Arrangement, Operation and	4

	control of UPFC- Basic principle of P and Q control, independent real and reactive power flow control- Applications	
5.2	Static Voltage and Phase Angle Regulators: TCVR and TCPAR	3
5.3	The Interline Power Flow Controller (IPFC)	1

Reference Books

1. N. G. Hingorani and L. Gyugyi, “Understanding FACTS”, IEEE Press, 2000

2. K R Padiyar, “FACTS Controllers in Power Transmission and Distribution”, New Age International Publishers, 2007

3. Y.H. Song and A.T. Johns, “Flexible ac Transmission Systems (FACTS)”, IEE Press, 1999

4. T J E Miller, "Reactive Power Control in Power Systems'', John Wiley, 1982

5. J Arriliga and N R Watson, "Computer modeling of Electrical Power Systems”, Wiley, 2001

6. Ned Mohan et. al "Power Electronics”, John Wiley and Sons

7. https://nptel.ac.in/courses/108107114

221EEE019	DIGITAL PROTECTION OF POWER SYSTEMS	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 2	3	0	0	3

Preamble:

The objective of this course is to deliver advanced techniques in relaying and protection. It covers different relay protection schemes for various applications such as protection of transmission lines, bus bars, transformer and generator. It is also explaining the load shedding schemes and principles of protection of ac, dc and hybrid micro grid.

Prerequisites: Nil

Course Outcomes:

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

CO 1	Identify the different relay protective schemes for various applications.
CO 2	Understand the practical considerations for selection of various algorithms in digital relay protection schemes.
CO 3	Understand the protection of transmission lines, bus bar and transformer
CO 4	Explain load shedding and frequency relaying schemes
CO 5	Describe the principles of protection of ac, dc and hybrid microgrid

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	3 hours

Continuous Internal Evaluation Pattern:

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

EE3

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

Test paper, 1 no. : **10 marks**

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

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

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

EE3

Model Question Paper

E

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, MONTH YEAR

ELECTRICAL AND ELECTRONICS ENGINEERING

Streams: POWER SYSTEMS

221EEE019 DIGITAL PROTECTION OF POWER SYSTEMS

Max. Marks: 60 Duration:2.5 Hours

Part A
Answer ALL Questions

1	Why is percentage differential relay more stable than simple differential relay	(5)
2	With the help of a block diagram explain the basic components of a digital relay.	(5)
3	Explain the power swing detection and blocking technique in digital distance Relays.	(5)
4	Explain the hazards and risk of islanding.	(5)
5	What are the challenges in protection of dc microgrids.	(5)

(5x5=25 marks)

Part B
Answer any FIVE full Questions

6	What are the various overcurrent protective schemes? Discuss their merits, demerits and field of application.	(7)
7	Explain the full cycle window algorithm and half cycle window algorithm. What is the difference between these two algorithms?	(7)
8	a) In what way is the distance protection superior to over current protection for the protection of transmission lines.	(3)
	b) Explain the differential protection used for the protection of a transformer.	(4)
9	What are the factors to be considered in load shedding	(7)
10	What are the features of digital frequency relays	(7)
11	a) What are the challenges in the protection of dc mico grid	(3)
	b) Why travelling based protection schemes are used for the protection of transmission lines	(4)

EE3

Syllabus

No	**Topic**
1	**Introduction to Relays (10 hours)**
	Introduction: Need for protective systems, Zones of protection Current transformers and potential transformers /Capacitive voltage transformers Relays: Over current relays-time - current characteristics of Instantaneous over current relays, definite time over current relays, directional over current relay, current setting and time setting-simple problems, comparison with conventional relays - differential relays, operating and restraining characteristics, types of differential relays - types of distance relays- (basic principles only)
2	**Introduction of Digital Relays (8 hours)**
	Introduction of digital relays, Fundamentals of digital relays, Basic layout and elements of digital relays The concept of sampling and aliasing of digital relays, Sliding window concept of digital relays Estimation of phasors using Full-cycle Discrete Fourier Transform(DFT), Estimation of phasors using Half- cycle DFT Introduction of Discrete Cosine Transform; Estimation of phasors using Walsh function technique and Least Error Square technique. Estimation of frequency in digital relays and practical considerations for selection of various algorithms.
3	**Protection of Transmission Line Systems, Bus-bar, Transformer and Generator (10 hours)**
3.1	Principle of distance relaying, schemes of distance protection, Differential line protection, Phase comparison line protection Effect of power swings on the performance of distance relays. Computation of direction and impedance for digital distance relays, Power swing detection and blocking technique in digital distance Relays Protection of double- circuit transmission line using digital distance relays; Protection of multi terminal transmission line using digital distance relays; Protection of series compensated transmission line using digital distance relays. Pilot relaying schemes: Pilot wire protection, carrier current protection Protection of Bus-bar, Transformer and Generator *:* Types of faults, differential protection, harmonic restraint relay, Stator and rotor protection against various types of faults.
4	**Load shedding and Frequency relaying (6 hours)**
	Various load shedding techniques and frequency relays Load shedding and Frequency relaying: Factors to be considered and rate of frequency decline Islanding phenomena: Hazards and risk of islanding and methods of islanding Loss of existing protection coordination among protective devices
5	**Protection of ac, dc and hybrid ac-dc micro grid (8 hours)**
	Protection of dc micro grid: Review and challenges- AC micro grid protection: Problems and solutions- Insight in to hybrid ac-dc micro grid protection Application of travelling wave (TW) and wavelet transform (WT) Protection of High voltage dc transmission network Various cyber attacks at substation/transmission level for Indian power grid network; Basic concept and application of control switching

EE3

Course Plan

No	Topic	No. of Lectures
1	**Introduction to Relays**	
1.1	Introduction: Need for protective systems, Zones of protection	1
1.2	Current transformers and potential transformers /Capacitive voltage transformers	2
1.3	Relays: Over current relays-time - current characteristics of Instantaneous over current relays, definite time over current relays, directional over current relay	2
1.4	current setting and time setting-simple problems, comparison with conventional relays	1
1.5	differential relays, operating and restraining characteristics, types of differential relays	2
1.6	types of distance relays- (basic principles only)	2
2	**Introduction of Digital Relays**	
2.1	Introduction of digital relays, Fundamentals of digital relays, Basic layout and elements of digital relays	2
2.2	The concept of sampling and aliasing of digital relays, Sliding window concept of digital relays	1
2.3	Estimation of phasors using Full-cycle Discrete Fourier Transform (DFT), Estimation of phasors using Half- cycle DFT	2
2.4	Introduction of Discrete Cosine Transform; Estimation of phasors using Walsh function technique and Least Error Square technique.	2
2.5	Estimation of frequency in digital relays and practical considerations for selection of various algorithms.	1
3	**Protection of Transmission Line Systems, Bus-bar, Transformer and Generator**	
3.1	Principle of distance relaying, schemes of distance protection, Differential line protection, Phase comparison line protection	1
3.2	Effect of power swings on the performance of distance relays. Computation of direction and impedance for digital distance relays, Power swing detection and blocking technique in digital distance Relays.	2
3.3	Protection of double- circuit transmission line using digital distance relays; Protection of multi terminal transmission line using digital distance relays; Protection of series compensated transmission line using digital distance relays.	3
3.4	**Pilot relaying schemes:** Pilot wire protection, carrier current protection	2
3.5	**Protection of Bus-bar, Transformer and Generator :** Types of faults, differential protection, harmonic restraint relay, Stator and rotor protection against various types of faults.	2
4	**Load shedding and Frequency relaying**	
4.1	Various load shedding techniques and frequency relays	1
4.2	Load shedding and Frequency relaying: Factors to be considered and rate of frequency decline	2
4.3	Islanding phenomena: Hazards and risk of islanding and methods of islanding	2
4.4	Loss of existing protection coordination among protective devices	1
5	**Protection of ac, dc and hybrid ac-dc micro grid**	
5.1	Protection of dc micro grid: Review and challenges	1

EE3

5.2	AC micro grid protection: Problems and solutions	1
5.3	Insight in to hybrid ac-dc micro grid protection	1
5.4	Application of travelling wave (TW) and wavelet transform (WT)	2
5.5	Protection of High voltage dc transmission network	1
5.6	Various cyber-attacks at substation/transmission level for Indian power grid network; Basic concept and application of control switching	2

Reference Books

1. A. T. Johns and S. K. Salman, "Digital Protection for Power Systems," Peter Peregrinus Ltd, UK, 1995.
2. Waldemar Rebizant, Digital Signal Processing in Power System Protection and Control – Springer Publication
3. J. L. Blackburn, "Applied Protective Relaying," Westinghouse Electric Corporation, New York, 1982.
4. A. G. Phadke and J. S. Thorp, "Computer Relaying for Power Systems," Research study press Ltd, John Wiley & Sons, Taunton, UK, 1988.
5. S.P Patra, S.K Bl,lsu and S. Choudhary, "Power System Protection", Oxford IBH Pub.
6. S. Ravindernath and M. Chander, "Power System Protection and Switchgear", Wiley Eastern Ltd.
7. Badri Ram and Vishwakarma, Power System Protection and Switchgear, TAT A McGraw Hill.
   Anderson, P.M., Power System Protection, IEEE Press, New York, 1999.
8. Blackburn, J.L., Applied Protective Relaying, Westinghouse Electric Corporation, New . York, 1982
9. Bhavesh Bhalja, R. P. Maheshwari, N. G. Chothani, Protection and Switchgear, Oxford University Press, 2nd edition, New Delhi, India, 2018
10. Oza, B. A., N. C. Nair, R. P. Mehta, et al., Power System Protection & Switchgear, Tata McGraw Hill, New Delhi, 2010 .
11. Phadke, A.G. and J.S. Thorp, Computer Relaying for Power Systems, Research Study Press Ltd, John Wiley & Sons, Taunton, UK, 1988
12. Bhavesh Bhalja and Vijay H. Makwana, ""Transmission Line Protection Using Digital Technology,""Springer Science+Business Media Singapore Pte. Ltd; Singapore, January 2016

EE3

CODE 221EEE020	POWER SYSTEM INSTRUMENTATION	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 2	3	0	0	3

Preamble:
The objective of this course is to deliver advanced techniques in power system Instrumentation. It covers different measuring instruments and schemes for various areas of the power system such as generation transmission and distribution. It is also explaining the distribution automation and substation automation with the explanation of SCADA and PMU implementation. Upon successful completion of this course, students will be able to analyse the performance of measuring instruments and various controls in the power system, and use it for different applications.

Prerequisites: Nil

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

CO 1	Understand the concept of errors and differentiate various transducers
CO 2	Design newer procedures and better methods for effective instrumentation systems for power networks.
CO 3	Use various control techniques and measurement methods involved in power plant
CO 4	Implement various control schemes applied to distribution automation and substation automation
CO 5	Understand the basics of instrumentation SCADA system and PMU implementation in Power System

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

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

EE3
Course based task/Seminar/Data collection and interpretation: **15 marks**
Test paper, 1 no. : **10 marks**
Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

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

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

EE3

Model Question paper

E

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, MONTH YEAR

ELECTRICAL AND ELECTRONICS ENGINEERING

Stream: POWER SYSTEMS

221EEE020 POWER SYSTEM INSTRUMENTATION

Max. Marks: 60. Duration: 2.5 Hours

Part A
Answer ALL Questions

1	Describe the static and dynamic characteristics of Measuring Instruments	(5)
2	Discuss the working of a load cell	(5)
3	Explain the methods for the measurement of high AC voltage.	(5)
4	Explain the transmission line sag measurement using triangulation technique	(5)
5	Write short notes on Phasor Measurement Units	(5)

(5x5=25 marks)

Part B
Answer any FIVE full Questions

6	a) List the different types of errors in measurements?	(3)
	b) Define the following terms in measurement i) Accuracy ii) Resolution iii) Precision	(4)
7	a) Describe the data logger system with the help of suitable block diagram	(3)
	b) Classify transducers with examples. Differentiate between sensors and actuators.	(4)
8	Draw the equivalent circuit and phasor diagram of a current transformer. Derive the expression for ratio and phase angle errors	(7)
9	List and explain the input and output variables involved in power plant instrumentation	(7)
10	Explain the operation of digital relays in transmission line protection. State its performance with electronic relays.	(7)
12	Explain with the help of characteristics the role of P-f control in power system	(7)

Syllabus

I	Generalized performance characteristics of instruments – Static and dynamic characteristics, development of mathematical model of various measurement systems. Classification of instruments based on their order. Dynamic response and frequency response studies of zero order, first order and second order instruments. Theory of errors: systematic and random errors, limits of error, probable error and standard deviation. Gaussian error curves, combination of errors.	6
II	Transducers: classification & selection of transducers, inductive & capacitive transducers, thermocouples, photo-diodes & photo-transistors, encoder type digital transducers Signal Conditioning: Introduction, Signal Processing and its Components, Instrumentation Amplifier. Electrical Isolators, Frequency to Voltage Converters, Grounding and Shielding.	10
III	Measurement of voltage, current, phase angle, frequency, active power and reactive power in power plants. Energy meters and multipart tariff meters. Capacitive voltage transformers and their transient behaviour, Current Transformers for measurement and protection, composite errors and transient response	7
IV	Basics of power plant operation- major input variables, major control variables Automation strategy: Distributed hierarchical system. Computer Control of Power Plant: IS specification: Introduction, Application and Relevancy of IS specification in perspective of power system instrumentation. Transmission Lines: Fibre optics meter for high voltage and high current measurement, Transmission line sag measurement using triangulation technique. Review on protective relays	9
V	Distribution Automation: Definitions, management information systems (MIS) ,Tariff, automatic meter reading (AMR) , Remote control load management. Control of voltage, frequency and tie-line power flows, Q-V and P-f control loops. Mechanism of real and reactive power control. Introduction to SCADA: Data acquisition systems, Evolution of SCADA, Communication technologies, Monitoring and supervisory functions, SCADA applications in Utility Automation, Industries. Introduction to PMUs and their placement.	9

EE3

Course Plan

No	Topic	No. of Lectures
1	Generalized performance characteristics of instruments	
1.1	Static and dynamic characteristics, development of mathematical model of various measurement systems.	1
1.2	Classification of instruments based on their order. Dynamic response and frequency response studies of zero order, first order and second order instruments.	2
1.3	Theory of errors: systematic and random errors, limits of error, probable error and standard deviation.	2
1.4	Gaussian error curves, combination of errors.	1
2	**Transducers and Signal Conditioning**	
2.1	Transducers, classification & selection of transducers	2
2.2	inductive & capacitive transducers	1
2.3	Thermocouples, photo-diodes & photo-transistors	1
2.4	Encoder type digital transducers	2
2.5	Introduction, Signal Processing and its Components	1
2.6	Instrumentation Amplifiers , Electrical Isolators	1
2.7	Frequency to Voltage Converters, Grounding and Shielding.	2
3	**Measurement of Electrical quantities**	
3.1	Measurement of voltage, current, phase angle, frequency, active power and reactive power in power plants.	2
3.2	Energy meters and multipart tariff meters.	2
3.3	Capacitive voltage transformers and their transient behaviour,	1
3.4	Current Transformers for measurement and protection, composite errors and transient response	2
4	Basics of power plant operation and Computer Control of Power Plant	
4.1	Major input variables, major control variables.	1
4.2	Automation strategy: Distributed hierarchical system.	1
4.3	IS specification: Introduction, Application and Relevancy of IS specification in perspective of power system instrumentation.	2
4.4	Fibre optics meter for high voltage and high current measurement	1
4.5	Transmission line sag measurement using triangulation technique.	1
4.6	Review on protective relays : Proactive Relays: Organization of protective relay.	1
4.7	Single input, two-input and multi-input relays.	1
4.8	Electromagnetic, electronic and digital relays.	1
5	Distribution Automation and Control	
5.1	Definitions of management information systems (MIS)	1
5.2	Definition and types of Tariff	1
5.3	Automatic meter reading (AMR), Remote control load management.	2
5.4	Control of voltage, frequency and tie-line power flows, Q-v and P-f control loops.	2
5.5	Mechanism of real and reactive power control.	1
5.6	Introduction to SCADA: Data acquisition systems, Evolution of SCADA, Communication technologies, Monitoring and supervisory functions, SCADA applications in Utility Automation, Industries.	1
5.7	Introduction to PMUs and their placement.	1

Reference Books

1. B. D. Doeblin, 'Measurement systems - Application and Design', McGraw-Hill, New York.
2. Power System Instrumentation By Ramnath.Author Ramnath Publisher Genius Publication
3. J. W. Dally, W. F. Reley and K. G. McConnel, 'Instrumentation for Engineering Measurements' Second Edition, John Wiley & Sons Inc. New York, 1993
4. Helfrick and Cooper, 'Modern Electronic Instrumentation and Measurement Techniques', Prentice-Hall of India
5. Jones, B. E., 'Instrumentation Measurement and Feedback', Tata McGraw Hill, 1986.
6. Golding, E. W., 'Electrical Measurement and Measuring Instruments', 3rd Edition Stuart A Boyer, "SCADA-Supervisory Control and Data Acquisition', Instrument Society of America Publications,USA,2004
7. Modern Power Station Practice – Vol: C, Vol: D, Pergamon Press
8. Principles of Industrial Instrumentation - D Patranabish, TMH, New Delhi
9. Industrial Instrumentation Control and Automation – S Mukhopadhyay, S.Sen, A. Deb – Jaico Publishing House,Mumbai.
10. D.P. Kothari & J.S. Dhillon, " Power System Optimization", PHI, 2010.
11. Electrical Instrumentation by U.A. Bakshi, A.V. Bakshi, K.A. Bakshi, Technical Publication Pune.
12. C. L. Wadhawa "Electrical Power System" 6th edition, New Age International Publication Delhi.
13. S. Sivanagaraju & G. Sreenivasan, "Power System operation and Control", Pearson 2010.
14. A.G. Phadke & J.S. Thorp, "Synchronized Phasor Measurements and Their Applications" Springer publication, 2008.
15. Stuart A., Supervisory Control and Data Acquisition, Boyer International Society of Automation

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221EEE021	**RESTRUCTURED POWER SYSTEM**	**PROGRAM ELECTIVE 2**	**3**	**0**	**0**	**3**

Preamble:
The objective of this course is to understand the electricity power business and technical issues in a restructured power system in both Indian and world scenarios.
Prerequisites: Nil

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

CO1	Acquire the knowledge of the new dimensions associated with the power system and explain the deregulated electricity market models functioning around the world.
CO2	Use different strategies in congestion management
CO3	Solve transmission pricing with loss allocation
CO4	Identify ancillary services for restructured power system
CO5	Outline the salient features of Indian Electricity Act and the formation and operation of Indian power exchanges.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

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

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

EE3

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

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

EE3

Model Question paper

QP CODE: **Pages: 2**

Reg No:_______________ **Name:_______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
FIRST SEMESTER M.TECH DEGREE EXAMINATION, MONTH & YEAR
Course Code: 221EEE021
Course Name: RESTRUCTURED POWER SYSTEM

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

PART A

Answer all Questions. Each question carries 5 marks

1. How a restructured power system differs from a monopoly system.
2. Define congestion management and explain its importance in a restructured power system.
3. Distinguish different methods of rolled transmission pricing methods.
4. What are the different ancillary services required under contingency conditions?
5. Give the merits of Indian power exchange for day-ahead market.

PART B

Answer any five Questions. Each Question carries 7 marks

6. Briefly explain various entities involved in power system deregulation
7. Describe the different types of market models in a restructured power system.
8. Discuss briefly price area congestion management in the power system under regulation environment.
9. Illustrate the basic principle of marginal transmission pricing paradigm.
10. Distinguish different classification of ancillary service depending up the service requirement.
11. Formulate the voltage control and reactive power support in ancillary service in power system under deregulated nature.
12. Discuss about the various challenges and opportunities in the implementation of open access in India.

No.	Syllabus
1	**Introduction to Restructuring of Power Industry (10 hours)**
	Introduction: Deregulation of power industry, Restructuring process, Issues involved in deregulation, Deregulation of various power systems. Fundamentals of Economics: Consumer behaviour, Supplier behaviour, Market equilibrium, Short and long run costs, Various costs of production. Market models: Market models based on Contractual arrangements, Comparison of various market models, Electricity vis – a – vis other commodities, Market architecture, Case study.
2	**Transmission Congestion Management (8 hours)**
	Introduction: Definition of Congestion - Importance of congestion management - Features of congestion management – Classification of congestion management methods – Calculation of ATC – Non market methods – Market methods – Nodal pricing – Inter zonal and Intra zonal congestion management – Price area congestion management – Capacity alleviation method.
3	**Pricing of Transmission Network Usage and Loss Allocation (8 hours)**
	Introduction to transmission pricing – principles of transmission pricing – Classification of transmission pricing methods – Rolled-in transmission pricing methods – Marginal transmission pricing paradigm – Composite pricing paradigm – Comparison between different paradigms – Issues in transmission pricing. Introduction to loss allocation – classification of loss allocation methods – Comparison between various methods
4	**Ancillary Service Management (8 hours)**
	Introduction of ancillary services – Types of Ancillary services – Classification of Ancillary services – Load generation balancing related services Voltage control and reactive power support devices – Black start capability service – method to obtain ancillary service –Co-optimization of energy and reserve services - International comparison.
5	**Reforms in Indian Power Sector (8 hours)**
	Introduction – Framework of Indian power sector – Reform initiatives - **Availability based tariff (ABT)-** Electricity Act, 2003 – Open access issues and solution - Developing power exchanges suited to the Indian market - Indian power market - Indian energy exchange - Indian power exchange - Day Ahead Market - Online power trading.

EE3

Course Plan

No.	Topic	No. of Lectures
1	**Introduction to Restructuring of Power Industry**	
1.1	Introduction and deregulation of power industry	1
1.2	Understanding the restructuring process.	1
1.3	Issues involved in deregulation and Deregulation of various power systems.	1
1.4	Consumer behaviour, Supplier behaviour, Market equilibrium	2
1.5	Short and long run costs, Various costs of production	1
1.6	Market models based on Contractual arrangements - Comparison of various market models.	1
1.7	Electricity vis – a – vis other commodities	1
1.8	Market architecture	2
2	**Transmission Congestion Management**	
2.1	Definition of Congestion - Importance of congestion management - Features of congestion management	2
2.2	Classification of congestion management methods –	1
2.3	Calculation of ATC.	1
2.4	Non market methods – Market methods –	1
2.5	Nodal pricing	2
2.6	Inter zonal and Intra zonal congestion management – Price area congestion management – Capacity alleviation method.	2
3	**Pricing of transmission network usage and loss allocation**	
3.1	Introduction to transmission pricing and principles of transmission pricing.	1
3.2	Classification of transmission pricing methods – Rolled-in transmission pricing methods	3
3.3	Marginal transmission pricing paradigm – Composite pricing paradigm	1
3.4	Comparison between different paradigms – Issues in transmission pricing.	1
3.5	Introduction to loss allocation – classification of loss allocation methods – Comparison between various methods.	2
4	**Ancillary Service Management**	
4.1	Introduction of ancillary services, Types of Ancillary services and classification of Ancillary services.	2
4.2	Load generation balancing related services	1
4.3	Voltage control and reactive power support devices	2
4.4	Black start capability service and method to obtain ancillary service	1
4.5	Co-optimization of energy and reserve services	1
4.6	International comparison	1
5	**Reforms in Indian Power Sector**	
5.1	Framework of Indian power sector	1
5.2	Reform initiatives	1
5.3	Availability based tariff (ABT)	1
5.4	Electricity Act, 2003	1

5.5	Open access issues and solution	1
5.6	Developing power exchanges suited to the Indian market - Indian power market - Indian energy exchange - Indian power exchange -	2
5.7	Day Ahead Market - Online power trading.	1

Text Books

1. Loi Lei Lai, ‘Power System Restructuring and Deregulation’, John Wiley & Sons Ltd., 2001.
2. Steven Stoft, “Power system economics: designing markets for electricity”, John Wiley & Sons, 2002.
3. Mohammad Shahidehpour, Hatim Yamin, ‘Market operations in Electric power systems’, John Wiley & son ltd.,2002.
4. Lorrin Philipson, H. Lee Willis, ‘Understanding Electric Utilities and Deregulation’ Taylor & Francis, 2006.
5. Mohammad Shahidehpour, Muwaffaq Alomoush, ‘Restructured Electrical Power Systems’, Marcel Dekker, Inc., 2001.

References

1. R. G. Yadav, A. Roy, S. A. Khaparde and P. Pentayya, India’s fast growing power sector, IEEE Power and Energy Magazine, July / August 2005.
2. S. A. Khaparde and A. K. Sardana, Powering progress, IEEE Power and Energy Magazine, July / August 2007.

CODE 221EEE022	COURSE NAME CUSTOM POWER DEVICES	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 2	3	0	0	3

Preamble:
Power systems are subjected to various disturbances such as voltage sag, swell, unbalance, etc. It is very important that depending upon the criticality of the customer's load, the necessary compensation should be provided. The aim of the course is to look into various custom power devices used for compensation of currents and voltage in the distribution system after looking into the power quality aspects.

Prerequisites: Nil

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

CO 1	Illustrate power quality problems to customers
CO 2	Analyse power quality problems
CO 3	Classify custom power devices used in distribution systems
CO 4	Analyse the operation of DSTATCOM
CO 5	Analyze the operation of DVR and UPFC

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:
Preparing a review article based on peer reviewed Original publications (minimum 10 publications shall be referred): **15 marks**
Course based task/Seminar/Data collection and interpretation: **15 marks**
Test paper, 1 no. : **10 marks**
Test paper shall include minimum 80% of the syllabus.
Note: SCILAB/MATLAB based simulation work can also be considered for course-based task.

EE3

End Semester Examination Pattern:

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

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

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

EE3

Model Question paper

E

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 20XX

ELECTRICAL AND ELECTRONICS ENGINEERING

Streams: POWER SYSTEMS

221EEE022 CUSTOM POWER DEVICES

Max. Marks: 60 Duration: 2.5 Hours

Part A
Answer ALL Questions

1	Distinguish between voltage sags and voltage swells in power system. Explain practical scenarios of voltage sags and swells in a power system.	(5)
2	Discuss Detroit Edison Sag Score and Voltage Sag Lost Energy Index (VSLEI).	(5)
3	Explain the topology and operating principle of a solid state current limiter.	(5)
4	Discuss the DSTATCOM Structure for a weak supply point connection.	(5)
5	Explain the working of a dc capacitor supported DVR.	(5)

(5x5=25 marks)

Part B
Answer any FIVE full Questions

6	Discuss the impacts of power quality problems on end users.	(7)
7	Explain the open loop and closed loop current balancing.	(7)
8	Describe the Sag/Swell Detection Algorithm based on Two-Axis Transformation.	(7)
9	Explain the methodology of generating reference currents using instantaneous PQ theory and instantaneous symmetrical Components.	(7)
10	With the help of a schematic, explain the right-shunt UPQC Structure and its control.	(7)
11	a) Write notes on network reconfiguring devices.	(3)
	b) Discuss the importance of DC capacitor control in a DSTATCOM.	(4)
12	a) Define SAIDI and CAIDI.	(3)
	b) Explain the State Feedback Control of DVR.	(4)

EE3

Syllabus

No	Topic	No. of Lectures
1	Introduction to Electric Power Quality, Classification of PQ issues, Power Quality Problems:	8
2	Analysis of Power Outages, Analysis of Unbalance, Analysis of Distortion, Analysis of Voltage Sag, Analysis of Voltage Flicker, Classical Load Balancing Problem	8
3	Power Quality Indices, Filters and Compensating devices, Solid State Limiting, Breaking and Transferring Devices	8
4	DSTACOM: Objectives, Topology, Working, V-I characteristics, Control mechanisms	8
5	DVR: Working, Control strategies, Structure UPQC: Objectives, Working, Configurations	8

Course Plan

No	Topic	No. of Lectures
1	**Introduction to Power Quality**	
1.1	Electric Power Quality: Definition of PQ - PQ issue-causes of disturbances in power system- Impacts of Power Quality Problems on End Users- Power Quality Standards -Power Quality Monitoring.	2
1.2	Classification of PQ issues: Transients, Short Duration Voltage Variations, Long Duration Voltage Variations, Voltage Imbalance, Waveform Distortion, Voltage Fluctuations, Power Frequency Variations, Power Acceptability Curves	3
1.3	Power Quality Problems: Poor Load Power Factor, Loads Containing Harmonics, Notching In Load Voltage, DC Offset In Loads, Unbalanced Loads, Disturbance In Supply Voltage	3
2	**Analysis and Conventional Mitigation Methods**	
2.1	Analysis of Power Outages	1
2.2	Analysis of Unbalance - Symmetrical Components of Phasor Quantities - Instantaneous Symmetrical Components - Instantaneous Real and Reactive Powers	2
2.3	Analysis of Distortion - On-Line Extraction of Fundamental Sequence Components from Measured Samples - Harmonic Indices	2
2.4	Analysis of Voltage Sag - Detroit Edison Sag Score - Voltage Sag Energy - Voltage Sag Lost Energy Index (VSLEI)	1
2.5	Analysis of Voltage Flicker - Reduced Duration and Customer Impact of Outages	1
2.6	Classical Load Balancing Problem - Open-Loop Balancing, Closed-Loop Balancing - Current Balancing -Harmonic Reduction -Voltage Sag Or Dip Reduction	1
3	**Power Quality Indices and Custom Power Devices**	
3.1	Power Quality Indices: Quality of electrical signal- system frequency variations-THD-degree of unbalance-phase displacement-voltage quality factor – power quality factor	3
3.3	Filters and Compensating devices: Types of nonlinear loads- Active and passive power filters for PQ improvement-Need of custom power devices -Network reconfiguring devices-compensating devices-	2
3.4	Solid State Limiting, Breaking and Transferring Devices: Solid State Current Limiter: Topology and Operating Principle, Solid State Breaker (SSB), Issues in Limiting and Switching Operations - Solid State Transfer Switch (SSTS)	3

EE3

4	**Distribution Static Compensator**	
4.1	Objectives of shunt compensation-Topology (VSI based and CSI based)	1
4.2	Working of D-STATCOM- V-I characteristics	1
4.3	Control mechanism for load compensation and voltage regulation-compensating single phase loads	1
4.4	Generating reference currents using instantaneous PQ theory- Generating reference currents using instantaneous symmetric components	2
4.5	Compensating Star Connected Loads - Compensating Delta Connected Loads	1
4.6	Generating Reference Currents when the Source Is Unbalanced: Compensating to Equal Resistance, Compensating to Equal Source Currents, Compensating To Equal Average Power.	1
4.7	DSTATCOM Current Control when source and load are unbalanced/distorted	1
5	**DVR and UPQC**	
5.1	Objectives of series compensation-Working of DVR-Control strategies of DVR arrangement	2
5.2	Series Compensation of Power Distribution System: Fundamental Frequency Series Compensator Characteristics, Transient Operation of Series Compensator when the Supply is Balanced, Transient Operation when the Supply is Unbalanced or Distorted-Strategy Based on Instantaneous Symmetrical Components, .	2
5.3	DVR Structure: Output Feedback Control of DVR - State Feedback Control of DVR - Voltage Restoration - Series Active Filter	1
5.4	Unified Power Quality Conditioner: Objectives of UPQC- Working	1
5.5	UPQC Configurations: Structure and Control of Right-Shunt UPQC- Harmonic Elimination Using Right-Shunt UPQC - Structure and Control of Left-Shunt UPQC	2

Text Books

1. Arindam Ghosh and Gerard Ledwich, “Power Quality Enhancement Using Custom Power Devices,” The Kluwer International Series, 2002.

Reference Books

1. IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems, 519-1992.
2. IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems, 519-1992.
3. Power System Harmonics, Arrillaga J and Watson N R, Second Edition, John Wiley & Sons, 2003.
4. Power Quality, C. Shankaran, CRC Press, 2001

EE3

CODE 221EEE023	E-MOBILITY	CATEGORY	L	T	P	CREDIT
		Program Elective 2	3	0	0	3

Preamble: Nil

Prerequisites: Nil

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

CO 1	Explain various characteristics of conventional vehicles and compare them with hybrid & electric vehicles
CO 2	Analyse the various drive train topologies for hybrid & electric vehicles
CO 3	Distinguish the various energy storage systems
CO 4	Examine impact of electric vehicles on power system
CO 5	Analyse the various energy management strategies

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Blooms Category	End Semester Examination
Apply	30%
Analyse	40%
Evaluate	30%
Create	-

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

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

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: 60 marks

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

EE3

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

Model Question paper

Reg No.:_______________ Name:__________________________

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

221EEE023 E-MOBILITY

Max. Marks: 60 Duration: 2.5 Hours

Part A
(Answer all questions)

		Marks
1.	Compare the performance of a conventional vehicle with a hybrid-electric vehicle.	[5]
2.	A PM brushless DC motor has a torque constant of 0.12 Nm/A referred to the DC supply. Estimate the no load speed in RPM when connected to a 48V DC supply.	[5]
3	Explain the factors to be considered while designing a hybrid electric vehicle.	[5]
4.	Describe the influence of electric vehicle on power system?	[5]
5.	Describe the electric vehicle charging standards?	[5]

Part B
(Answer any five questions)

6	State and explain the dynamic equation of vehicle motion	[7]
7	Explain the different power flow control modes of a typical parallel hybrid system with the help of block diagrams.	[7]
8	Draw three different configurations of drive trains in electric vehicles. Briefly explain each configuration.	[7]
9	Describe the different battery charging modes? Compare them in detail.	[7]
10.	Explain hybridization of different energy storage devices	[7]
11	With the help of case studies, explain the impact of electric vehicles on system demand.	[7]
12	Classify and explain the different energy management strategies in electric vehicles.	[7]

Syllabus

Module 1: 8 Hours

Introduction to Hybrid & Electric Vehicles: Review of Conventional Vehicle, basics of vehicle performance, vehicle power source characterization, Transmission characteristics, mathematical models to describe vehicle performance, Basic principles and trends of smart mobility, concept of e-mobility, Introduction to Hybrid Electric Vehicles: Types of EVs, Hybrid Electric Drive-train, Tractive effort in normal driving, Drive cycles and their impact on vehicle operation

Module 2: 8 Hours

Hybrid Electric Drive-trains: Concept of Hybrid Electric Drive Trains, Architecture of Hybrid Electric Drive Trains, Series Hybrid Electric Drive Trains, Parallel hybrid electric drive trains, Electric Propulsion unit, Configuration and control of brushless DC Motor drives, Induction Motor drives, Permanent Magnet Motor drives, switched reluctance motor

Module 3: 8 Hours

Energy storage System: Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Hybridization of different energy storage devices, Sizing the drive system, Design of Hybrid Electric Vehicle and Plug-in Electric Vehicle

Module 4: 7 Hours

Influence of EVs on power system: Introduction, identification of EV demand, EV penetration level for different scenarios, classification based on penetration level, EV impacts on system demand: dumb charging, multiple tariff charging, smart charging, case studies

Module 5: 9 Hours

Energy Management System: Energy Management Strategies, Automotive networking and communication, EV charging standards, V2G, G2V, V2B, V2H, Business: E-mobility business, electrification challenges, Connected Mobility and Autonomous Mobility- case study Emobility Indian Roadmap Perspective, Policy: EVs in infrastructure system, integration of EVs in smart grid, social dimensions of EVs.

Course Plan

No	Topic	No. of Lectures
1	**Introduction to Hybrid & Electric Vehicles**	**(8 hours)**
1.1	Review of Conventional Vehicle, basics of vehicle performance, vehicle power source characterization	2
1.2	Transmission characteristics, mathematical models to describe vehicle performance	1
1.3	Basic principles and trends of smart mobility, concept of e-mobility,	
1.4	Introduction to Hybrid Electric Vehicles: Types of EVs, Hybrid Electric Drive-train, Tractive effort in normal driving	4
1.5	Drive cycles and their impact on vehicle operation	1
2	**Hybrid Electric Drive-trains**	**(8 hours)**
2.1	Concept of Hybrid Electric Drive Trains	1
2.2	Architecture of Hybrid Electric Drive Trains, Series Hybrid Electric Drive Trains, Parallel hybrid electric drive trains	2
2.3	Electric Propulsion unit, Configuration and control of brushless DC Motor drives	1
2.4	Induction Motor drives, Permanent Magnet Motor drives,	4

	switched reluctance motor	
3	**Energy storage System**	**(8 hours)**
3.1	Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles	2
3.2	Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis	2
3.3	Hybridization of different energy storage devices.	2
3.4	Sizing the drive system, Design of Hybrid Electric Vehicle and Plug-in Electric Vehicle	2
4	**Influence of EVs on power system**	**(7 hours)**
4.1	Introduction, identification of EV demand	2
4.2	EV penetration level for different scenarios, classification based on penetration level	2
4.3	EV impacts on system demand: dumb charging, multiple tariff charging, smart charging, case studies	3
5	**Energy Management System**	**(9 hours)**
5.1	Energy Management Strategies, Automotive networking and communication, EV charging standards, V2G, G2V, V2B, V2H.	3
5.2	Business: E-mobility business, electrification challenges Connected Mobility and Autonomous Mobility- case study Emobility Indian Roadmap Perspective.	3
5.3	Policy: EVs in infrastructure system, integration of EVs in smart grid, social dimensions of EVs.	3

Text Books

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

Reference Books

1. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley
2. R. Krishnan, Permanent Magnet Synchronous and Brushless DC Motors Drives, CRC Press
3. John G. Hayes, Abas Goodarzi, Electric Powertrain Energy Systems, Power Electronics and Drives for Hybrid, Electric and Fuel Cell Vehicles, Wiley

EE3

CODE 221EEE024	COURSE NAME Transient Analysis in Power System	CATEGORY	L	T	P	CREDIT
		Program Elective - II	3	0	0	3

Preamble:

Transient analysis has become a fundamental methodology for understanding the performance of power systems, determining power component ratings, explaining equipment failures, or testing protection devices. The study of transients is a mature field that can help to analyse and design modern power systems by knowing the characteristics or the behaviour of system undervarious conditions.

Prerequisites: Nil

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

CO 1	Analyse the basic causative objects of transient generation in power systems.
CO 2	Understand travelling waves and energy distribution in various sorts of fields.
CO 3	Evaluate different kinds of transient effects on power system equipment's.
CO 4	Apply various aspects of transient voltage distribution in power system equipment's.
CO 5	Understand power system protective methods during transient response.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	30%
Analyse	40%
Evaluate	25%
Create	5%

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 Marks:

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

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: Full Topics (60 Marks)

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

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

Model Question paper

QP CODE: **PAGE 1of 1**

Reg No:_____________ **Name:_______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 221EEE024

Course Name: Transient Analysis in Power System

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

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

1) What is switching transients? Plot the characteristics of voltage and current transients in LCcircuit.
2) Derive and explain the concept of energy components in travelling waves.
3) Explain the phenomena of interrupting small inductive and capacitive currents from acircuit.
4) Explain the consequences of voltage surges in generators and transformers,
5) Define and plot the transient recovery voltage for a LG fault.

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

6) What are different types of transients in power system? Explain the wave shape of lightninginduced currents. (7)
7) Derive and explain Telegraph equations for lossless and distortion less lines. (7)
8) With suitable diagram explain the generation of 3 phase capacitor switching transient. (7)
9) Explain the surge voltage distribution in transformer and motor during transients. (7)
10) Briefly explain the followings with suitable diagrams
    i) Surge diverter's (2)
    ii) Surge absorbers (2)
    iii) Insulation coordination (3)
11) Explain the followings with necessary equations and plots;
    i) Modelling of transient analysis (3.5)
    ii) Lattice diagram (3.5)
12) a) What is transformer inrush current? How can protect the transformer from inrush current. Explain with suitable diagram. (3.5)

    b) Enumerate various modern lightning arrestors used in power system protection. Explain.

    (3.5)

Syllabus and Course Plan:

No	Topic - Transient Analysis in Power System	No. of Lectures
1	**Module : I**	
1.1	Power system components – Introduction, Basic Concepts and Simple Switching Transients – switching an LR, LC and LCR circuits. Modelling for transient analysis.	3
1.2	Transients in power system – Effects of transients in power system, Types of transients. Internal and external causes of over voltages.	3
1.3	Lightning Induced Transients, mathematical model to represent lightning. Wave shape of the Lightning Current, Direct lightning stroke to transmission line tower, line conductor.	4
2	**Module : II**	
2.1	Travelling waves in transmission lines – Velocity of Travelling Waves and Characteristic Impedance.	3
2.2	Energy Contents of Travelling Waves - Circuits with distributed constants – Wave equations. The Telegraph Equations – for lossless line and distortion less line. The Lattice Diagram and its explanation	4
2.3	Reflection and refraction of travelling waves – Reflection of Travelling Waves against Transformer- and Generator Windings - Travelling waves at different line terminations.	3
3	**Module : III**	
3.1	Switching transients –double frequency transients – abnormal switching transients.	3
3.2	Switching transients during interrupting capacitive currents-Capacitive inrush currents. Interrupting Small Inductive Currents - TransformerInrush Currents.	5
3.3	Transients in switching a three phase reactor- three phase capacitor.	2
4	**Module : IV**	
4.1	Voltage distribution in transformer winding – voltage surges - Transformers – Generators and Motors.	4
4.2	Transient parameter values for transformers, reactors, generators and transmission lines.	4
5	**Module : V**	
5.1	Power System Transient Recovery Voltages - Characteristics of the Transient Recovery Voltage. The transient recovery voltage for different types of faults.	3
5.2	Basic ideas about protection –surge diverters-surge absorbers-protection of lines and stations.	3
5.3	Modern lighting arrestors, Insulation coordination, Protection of alternators and industrial drive systems.	4

Reference Books

1. Electrical Transients in power systems - Allan Greenwood 2nd edition 2010 - Wiley...
2. Transients in power systems - Lou van der Sluis, John wiley & sons 2001.
3. Introduction to Transient Analysis of Power Systems - Jose L. Naredo, Juan A. Martinez-Velasco -UNESCO-EOLS.
4. Travelling wave's and transmission systems - Bewley. LW, Dover publications, New York 1963.
5. High voltage measurements, testing and Design - Gallaghar PJ & Pearmain AJ, John Wiley& sons 2001.
6. Transients in Electrical Systems: Analysis, Recognition, and Mitigation - JC Das.
7. Transient Analysis of Power Systems-A Practical Approach, By Juan A. Martinez-Velasco-Wiley 2019.
8. Power System Transients- By Bibhu Prasad Ganthia, walnut publication 2021.

221LEE001	POWER SYSTEM LAB I	CATEGORY	L	T	P	CREDIT
		Laboratory	0	0	2	2

Preamble: The purpose of this lab is to provide a platform for the students to do hands-on practice with hardware and software tools to solve power system problems.

Prerequisite: Power Systems I

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

CO 1	Familiarize various application software packages in the power system field to solve and analyse power system problems.
CO 2	Realize operation and control of power system
CO 3	Analyse the various effects associated with the generation, transmission and distribution of electrical power.
CO 4	Familiarize with testing related to power system applications.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Continuous Internal Evaluation Pattern: 100 Marks

Practical Records /outputs- 40%

Regular Class Viva-Voce -20%

Final Assessment - 40%

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

List of Experiments

Software/simulation experiments

1. Z_{BUS} formation using building up algorithm
2. Load flow study using Gauss-Seidal method and Newton Raphson Method and test using
   a) A 5 bus system
   b) IEEE 14 bus system
3. Unit commitment problem solution using
   a) Priority method
   b) Dynamic Programming
4. Economic dispatch problem solution
5. Hydrothermal scheduling problem using lambda gamma method
6. Modelling and analysis of FACTS devices using suitable software tools
7. Perform contingency analysis of a given power system using suitable simulation software
8. Conduct transient stability analysis of standard test systems using suitable simulation software

Hardware experiments

9. Evaluate the power quality under various linear and non-linear loads.
10. Study of Ferranti effect in long transmission line
11. Study the relevance and effect of reactive power compensation in a power system

12. Measurement of sequence reactance of 3-phase alternator and 3-phase transformer.
13. Measurement of synchronous machine parameters – X_d, X_q, X_d’, Xq’, X_d”, X_q”, T_{do}’, T_{qo}’, T_{do}” and T_qo”.
14. Laboratory investigation on the behaviour of Solar PV cell/module.
15. Evaluate the characteristics of electromechanical and static/numerical relays
16. Conduct high voltage testing on various insulating materials

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

Reference Books

1. HadiSaadat, Power System Analysis, 2/e, McGraw Hill, 2002.
2. Kothari D. P. and I. J. Nagrath, Modern Power System Analysis, 2/e, TMH, 2009 3. M. S. Naidu, V. Kamaraju, High Voltage Engineering, Tata McGraw-Hill Education, 2004
3. Wadhwa C. L., Electrical Power Systems, 3/e, New Age International, 2009.