APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

# 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

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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**<br>**(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 $S = \{v_1, v_2, \ldots, v_n\}$ 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**<br>**(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) $\|f\|, \|g\|$ if $f(t) = t + 2, \quad g(t) = 3t - 2$ | (7) |

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| | | |
|---|---|---|
| 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 |

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| 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.

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**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 $\delta_i$ 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, $P_g$ = 0.5pu, $V_t$ = 1.0pu, $E_B$ = 1.0pu. The machine data: $X_d$ = 1.6pu, $X_q$ = 1.55pu, $X_d'$ = 0.32pu, $T_{do}'$ = 6.0s, 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

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**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<br>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.

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

| 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) |

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## 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** | |

| | | |
|---|---|---|
| 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 |

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**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

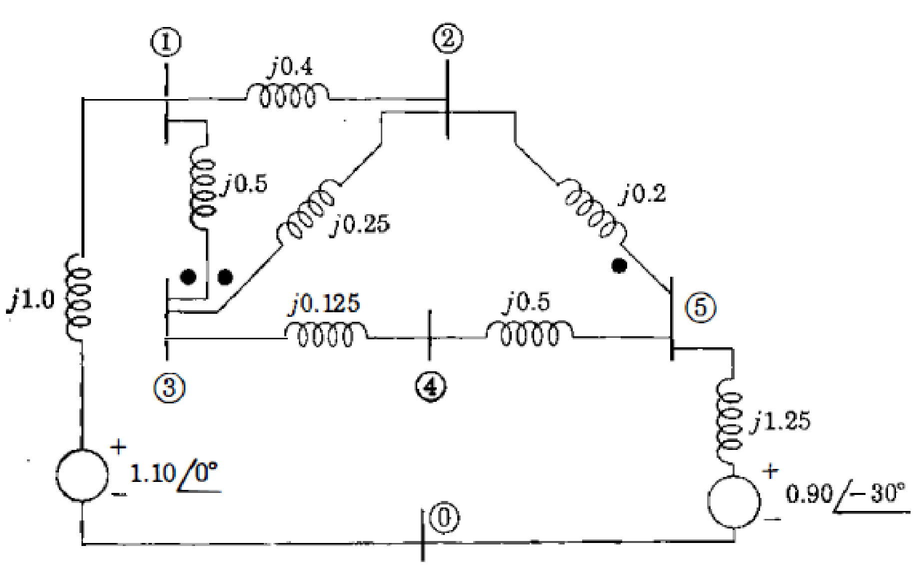
**Answer all Questions. Each question carries 5 marks**

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.

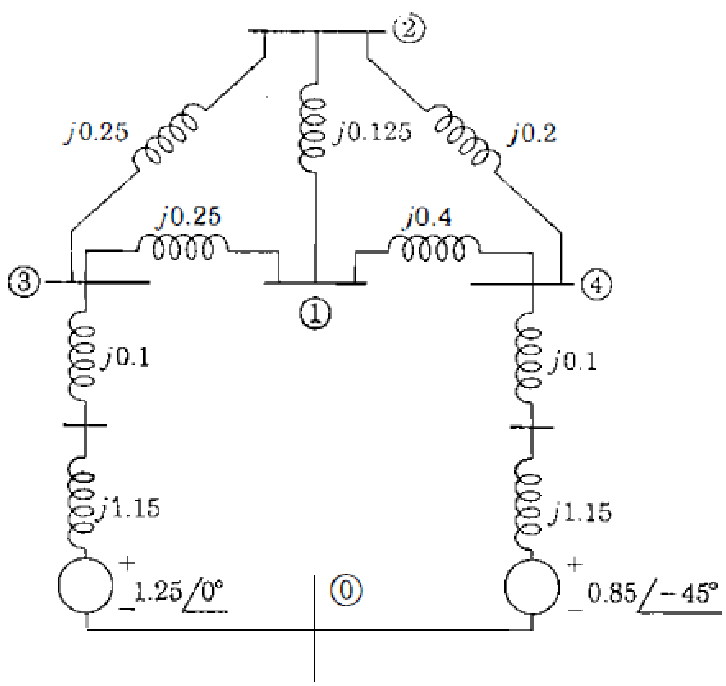
$$Y_{bus} = \begin{bmatrix} -j8.75 & j1.25 & j2.50 \\ j1.25 & -j6.25 & j2.50 \\ j2.50 & -j2.50 & -j5.00 \end{bmatrix} \qquad Z_{bus} = \begin{bmatrix} j0.16 & j0.08 & j0.12 \\ j0.08 & j0.24 & j0.16 \\ j0.12 & j0.16 & j0.34 \end{bmatrix}$$

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.<br>**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.<br>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.

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

| 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.

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.

**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 100mW/cm$^2$ has a fillfactor 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 PVarray. **(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)**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY KTU Estd. 2014

EE3

**Syllabus**

| No | Topic | No. of Lectures |
|---|---|---|
| 1 | **Present status of renewable energy technology, Fundamentals of Solar PV**<br>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<br>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<br>Fundamentals of Solar Radiation- Sun Earth angles; Relevance of Solar Resources Assessment in Solar PV<br>Plant Implementation; Solar Radiation Measurement Instruments- Pyranometer, Pyrheliometer; GIS Mapping of Solar Resource Potential | 8 |
| 2 | **PV System Design for Off-Grid Applications**<br>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.<br>Guidelines for selection of PV Modules, battery, Inverter, Protection devices.<br>Factors Affecting PV System Performance- Irradiance- Cell Temperature- Solar Altitude and Solar Spectrum | 8 |
| 3 | **Design of Grid-connected PV system**<br>Components of Grid connected PV system; Interface Requirements- IEEE 1547 -voltage-frequency-power quality-islanding<br>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<br>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<br>Inverter topologies in photovoltaic application<br>Control of grid connected PV systems - Renewable side controllers - MPPT control ; Grid-side controllers - Active and reactive power control<br>MPPT techniques for Solar PV- P & O algorithm, Incremental Conductance method- Temperature method | 8 |
| 4 | **Design of Wind energy conversion system**<br>Wind Data Analysis and Resource Estimation; Wind Measurement and Instrumentation; Wind Turbine Technology- Classification-based on axis of rotation-components<br>Wind Power Calculation- Wind Turbine Power Characteristic Curve-Stall control-Pitch angle Control-Tip speed ratio<br>Types of wind energy conversion systems- Type 1- Type 2- Type 3- Type-4, Type-5.<br>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<br>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<br>Grid-connected Turbine Operation<br>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**<br>Design of Small Hydro Power Systems- Head Measurement- Flow Measurement- Design of an Appropriate Turbine for Small Hydro Power Systems Projects<br>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<br>The importance of energy storage and distribution;<br>Small-Scale Electrical Energy Storage Systems-Batteries-Self discharge rate- discharge rate- State of Charge<br>Important Consideration in the Batteries' Design- Bank voltage- Bank capacity<br>Large-Scale Electrical Energy Storage Systems- Flywheel- Energy Storage Capacity- Principles of Energy Conversion- Energy Losses- Flywheel Subsystems | 8 |

**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<br>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<br>Control of grid connected PV systems - Renewable side controllers - MPPT control; Grid-side controllers - Active and reactive power control<br>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<br>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.<br>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<br>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;<br>Small-Scale Electrical Energy Storage Systems-Batteries-Self discharge rate- discharge rate- State of Charge<br>Important Consideration in the Batteries' Design- Bank voltage- Bank capacity<br>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.

| 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**.

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) |

******

**Syllabus**

| No | Topic | No. of Lectures |
|---|---|---|
| 1 | **Introduction to Smart Grid**<br>Evolution of Electric Grid, Concept of Smart Grid, Definitions<br>Need of Smart Grid, Functions of Smart Grid, Opportunities & Barriers of Smart Grid, Difference between conventional & smart grid<br>Concept of Resilient & Self-Healing Grid, Present development & International policies on Smart Grid. Case study of Smart Grid. | 8 |
| 2 | **Energy Management System (EMS)**<br>Smart substations - Substation Automation, Feeder Automation, SCADA, Smart Switchgear, Remote Terminal Unit, Intelligent Electronic Devices & their application for monitoring & protection, IEC 61850<br>Wide area monitoring, Phasor Measurement Unit, protection and control<br>Smart Integration of Energy Resources – Renewable, Intermittent Power Sources – Energy Storage, Impact of Plug-In Electric Vehicles | 8 |
| 3 | **Distribution Management System (DMS)**<br>Volt / VAR control, Fault Detection, Isolation and Service Restoration, Network Reconfiguration<br>Fault Current Limiting, Shunt Compensation (D-STATCOM, Active Filtering, Shunt Compensator With Energy Storage), Series Compensation<br>Outage Management System, Customer Information System, Geographical Information System<br>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**<br>Evolution of Electricity Metering, Smart Meters, Smart Appliances, Smart Sensors, Home & Building Automation<br>Advanced Metering Infrastructure (AMI), AMI Protocols – Standards and Initiatives<br>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**<br>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<br>Basics of Web Service and CLOUD Computing, Cyber Security for Smart Grid<br>Applications of smart grid to power systems and case study | 8 |

**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;<br>Operation Modes- Grid-connected operation- Islanded operation (basic principle only);<br>Control Modes: Microgrid control modes- Master–slave mode, Peer-to-peer mode, Combined mode<br>Control architectures in microgrid – Master slave with power-based control, Hierarchical control with centralized and distributed control<br>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-<br>DER technologies: Combined heat and power (CHP) systems- Wind energy conversion systems (WECS)<br>Solar photovoltaic (PV) systems-Small-scale hydroelectric generation-Storage devices. (principle of operation classification, advantages, disadvantages only) - Interconnection standards IEEE 1547 series<br>SCADA in Microgrids: Hardware components- Remote terminal unit Programmable logic controller- Master station and HMI computers- SCADA communication infrastructure<br>Impact of DG integration on power quality and reliability- Simple standby generation scheme - Secondary DG system with power quality<br>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<br>Inverter Control- Grid-Tie Inverter Control- Power Converter System Control<br>Grid Connection And Separation Control-- Grid Connection Control- Grid Separation Control<br>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<br>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<br>Fault Current Source for Effective Protection in Islanded Operation;<br>Fault Current Limitation in Microgrids;<br>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<br>Composition of the monitoring system- PV monitoring- Wind power monitoring- Microturbine monitoring- ES monitoring- Load monitoring<br>Design of the monitoring system<br>ENERGY MANAGEMENT- Forecast of DG- Load forecast- Frequency response characteristics of DG and loads- Power balance<br>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;<br>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<br>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-<br>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)<br>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<br>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;<br>Fault Current Limitation in Microgrids;<br>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<br>Composition of the monitoring system- PV monitoring- Wind power monitoring- Microturbine monitoring- ES monitoring- Load monitoring<br>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).

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.



APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
KTU
Estd.
2014

EE3

| CODE<br>221EEE017 | COURSE NAME<br>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 %

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY KTU Estd. 2014

EE3

**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 |

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

**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 %

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**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) |

**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<br>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<br>The concept of sampling and aliasing of digital relays, Sliding window concept of digital relays<br>Estimation of phasors using Full-cycle Discrete Fourier Transform(DFT), Estimation of phasors using Half- cycle DFT<br>Introduction of Discrete Cosine Transform; Estimation of phasors using Walsh function technique and Least Error Square technique.<br>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<br>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<br>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.<br>Pilot relaying schemes: Pilot wire protection, carrier current protection<br>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<br>Load shedding and Frequency relaying: Factors to be considered and rate of frequency decline<br>Islanding phenomena: Hazards and risk of islanding and methods of islanding<br>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<br>Application of travelling wave (TW) and wavelet transform (WT)<br>Protection of High voltage dc transmission network<br>Various cyber attacks at substation/transmission level for Indian power grid network; Basic concept and application of control switching |

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**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 |

| | | |
|---|---|---|
| 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 %

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**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<br><br>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.<br>Computer Control of Power Plant: IS specification: Introduction, Application and Relevancy of IS specification in perspective of power system instrumentation.<br><br>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.<br>Control of voltage, frequency and tie-line power flows, Q-V and P-f control loops. Mechanism of real and reactive power control.<br><br>Introduction to SCADA: Data acquisition systems, Evolution of SCADA, Communication technologies, Monitoring and supervisory functions, SCADA applications in Utility Automation, Industries.<br>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


APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY Estd. 2014

| 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 %

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# 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.

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| 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.<br>Fundamentals of Economics: Consumer behaviour, Supplier behaviour, Market equilibrium, Short and long run costs, Various costs of production.<br>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.<br>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<br>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. |

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**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 |

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| | | |
|---|---|---|
| 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.



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| CODE<br>221EEE022 | COURSE NAME<br>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.

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**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 %

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**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) |

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**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<br>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:<br>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:<br>Solid State Current Limiter: Topology and Operating Principle, Solid State Breaker (SSB), Issues in Limiting and Switching Operations - Solid State Transfer Switch (SSTS) | 3 |

| | | |
|---|---|---|
| 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:<br>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:<br>Output Feedback Control of DVR - State Feedback Control of DVR - Voltage Restoration - Series Active Filter | 1 |
| 5.4 | Unified Power Quality Conditioner:<br>Objectives of UPQC- Working | 1 |
| 5.5 | UPQC Configurations:<br>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

| 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).

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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** Marks

(Answer all questions)

| | | |
|---|---|---|
| 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,<br>V2G, G2V, V2B, V2H. | 3 |
| 5.2 | Business: E-mobility business, electrification challenges<br>Connected Mobility and Autonomous Mobility- case study<br>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<br>221EEE024 | COURSE NAME<br>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 %.

EE3

# 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 $T_q$o''.
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.

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 221RGE100 | RESEARCH METHODOLOGY & IPR | General Course | 2 | 0 | 0 | 2 |

**Preamble:**

This course introduces the strategies and methods related to scientific research. The students are also trained in the oral presentation with visual aids and writing technical thesis/reports/research papers. The salient aspects of publication and patenting along with the crucial role of ethics in research is discussed.

**Course Outcomes**

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

| | |
|---|---|
| **CO 1** | Approach research projects with enthusiasm and creativity. |
| **CO 2** | Conduct literature survey and define research problem |
| **CO 3** | Adopt suitable methodologies for solution of the problem |
| **CO 4** | Deliver well-structured technical presentations and write technical reports. |
| **CO 5** | Publish/Patent research outcome. |

**Mapping of course outcomes with program outcomes**

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

**Assessment Pattern**

| Bloom's Category | End Semester Examination |
|---|---|
| Apply | 70 % |
| Analyse | 30 % |
| Evaluate | |
| Create | |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern:**

Course based task: 15 marks

*Some sample course based tasks that can be performed by the student given below.*

- *Conduct a group discussion based on the good practices in research.*
- *Conduct literature survey on a suitable research topic and prepare a report based on this.*

Seminar: 15 marks

Test paper: 10 marks

**End Semester Examination Pattern:**

Total Marks: 60

The examination will be conducted by the respective college with the question provided by the University. The examination will be for 150 minutes and contain two parts; Part A and Part B. Part A will contain 6 short answer questions with 1 question each from modules 1 to 4, and 2 questions from module 5. Each question carries 5 marks. Part B will contain only 1 question based on a research article from the respective discipline and carries 30 marks. The students are to answer the questions based on that research article.

## Model Question paper

| | | | | |
|---|---|---|---|---|
| **QP Code:** | | | **Total Pages:** | |
| **Reg No.:** _______________ | | | **Name:** ___________________________ | |
| **APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**<br>**FIRST SEMESTER M. TECH DEGREE EXAMINATION, Month & Year** | | | | |
| **Course Code: 221RGE100** | | | | |
| **Course Name: RESEARCH METHODOLOGY & IPR** | | | | |
| **Max. Marks: 60** | | | **Duration: 2.5 Hours** | |

| | | | |
|---|---|---|---|
| | | **PART A** | |
| | | ***Answer all questions. Each question carries 5 marks*** | **Marks** |
| **1** | | Discuss the salient recommendations for great research recommended by Richard Hamming in his famous talk "You and Your Research" | **30** |
| **2** | | What are the characteristics of a good research question? Discuss with an example. | |
| **3** | | Explain the difference between continuum, meso-scale and micro scale approaches for numerical simulation. | |
| **4** | | Discuss any four rules of scientific writing. | |
| **5** | | What are the requirements for patentability? | |
| **6** | | What are the differences between copyright and trademark protection? | |
| | | Read the given research paper and write a report that addresses the following issues<br>**(The paper given can be specific to the discipline concerned**) | |
| **7** | | What is the main research problem addressed? | **3** |
| **8** | | Identify the type of research | **3** |
| **9** | | Discuss the short comings in literature review if any? | **6** |
| **10** | | Discuss appropriateness of the methodology used for the study | **6** |
| **11** | | Discuss the significance of the study and summarize the important results and contributions by the authors | **6** |
| **12** | | Identify limitations of the article if any. | **6** |

## Syllabus and Course Plan

| No | Topic | No. of Lectures |
|---|---|---|
| 1 | **Introduction** | |
| 1.1 | Meaning and significance of research, Skills, habits and attitudes for research, Types of research, | 1 |
| 1.2 | Characteristics of good research, Research process | 1 |
| 1.3 | Motivation for research: Motivational talks on research: "You and Your Research"- Richard Hamming | 1 |
| 1.4 | Thinking skills: Levels and styles of thinking, common-sense and scientific thinking, examples, logical thinking, division into sub-problems, verbalization and awareness of scale. | 1 |
| 1.5 | Creativity: Some definitions, illustrations from day to day life, intelligence versus creativity, creative process, requirements for creativity | 1 |
| 2 | **Literature survey and Problem definition** | |
| 2.1 | Information gathering – reading, searching and documentation, types of literature. | 1 |
| 2.2 | Integration of research literature and identification of research gaps | 1 |
| 2.3 | Attributes and sources of research problems, problem formulation, Research question, multiple approaches to a problem | 1 |
| 2.4 | Problem solving strategies – reformulation or rephrasing, techniques of representation, Importance of graphical representation, examples. | 1 |
| 2.5 | Analytical and analogical reasoning, examples, Creative problem solving using Triz, Prescriptions for developing creativity and problem solving. | 1 |
| 3 | **Experimental and modelling skills** | |
| 3.1 | Scientific method, role of hypothesis in experiment, units and dimensions, dependent and independent variables, control in experiment | 1 |
| 3.2 | precision and accuracy, need for precision, definition, detection, estimation and reduction of random errors, statistical treatment of data, definition, detection and elimination of systematic errors, | 1 |
| 3.3 | Design of experiments, experimental logic, documentation | 1 |

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| | | |
|---|---|---|
| 3.4 | Types of models, stages in modelling, curve fitting, the role of approximations, problem representation, logical reasoning, mathematical skills. | 1 |
| 3.5 | Continuum/meso/micro scale approaches for numerical simulation, Two case studies illustrating experimental and modelling skills. | 1 |
| 4 | **Effective communication - oral and written** | |
| 4.1 | Examples illustrating the importance of effective communication, stages and dimensions of a communication process. | 1 |
| 4.2 | Oral communication –verbal and non-verbal, casual, formal and informal communication, interactive communication, listening, form, content and delivery, various contexts for speaking- conference, seminar etc. | 1 |
| 4.3 | Guidelines for preparation of good presentation slides. | 1 |
| 4.4 | Written communication – Rules of scientific writing, form, content and language, layout, typography and illustrations, nomenclature, reference and citation styles, contexts for writing – paper, thesis, reports etc. Tools for document preparation-LaTeX. | 1 |
| 4.5 | Common errors in typing and documentation | 1 |
| 5 | **Publication and Patents** | |
| 5.1 | Relative importance of various forms of publication, Choice of journal and reviewing process, Stages in the realization of a paper. | 1 |
| 5.2 | Research metrics-Journal level, Article level and Author level, Plagiarism and research ethics | 1 |
| 5.3 | Introduction to IPR, Concepts of IPR, Types of IPR | 1 |
| 5.4 | Common rules of IPR practices, Types and Features of IPR Agreement, Trademark | 1 |
| 5.5 | Patents- Concept, Objectives and benefits, features, Patent process – steps and procedures | 2 |

## Reference Books


1. E. M. Phillips and D. S. Pugh, "How to get a PhD - a handbook for PhD students and their supervisors", Viva books Pvt Ltd.
2. G. L. Squires, "Practical physics", Cambridge University Press
3. Antony Wilson, Jane Gregory, Steve Miller, Shirley Earl, Handbook of Science Communication, Overseas Press India Pvt Ltd, New Delhi, 1st edition 2005
4. C. R. Kothari, Research Methodology, New Age International, 2004
5. Panneerselvam, Research Methodology, Prentice Hall of India, New Delhi, 2012.

6. Leedy P. D., Practical Research: Planning and Design, McMillan Publishing Co.
7. Day R. A., How to Write and Publish a Scientific Paper, Cambridge University Press, 1989.
8. William Strunk Jr., Elements of Style, Fingerprint Publishing, 2020
9. Peter Medawar, 'Advice to Young Scientist', Alfred P. Sloan Foundation Series, 1979.
10. E. O. Wilson, Letters to a Young Scientist, Liveright, 2014.
11. R. Hamming, You and Your Research, 1986 Talk at Bell Labs.

# SEMESTER II

Discipline: ELECTRICAL & ELECTRONICS

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

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

**Preamble:**

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

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

| | |
|---|---|
| **CO 1** | Apply numerical techniques to find the roots of nonlinear equations and solution of system of linear equations. |
| **CO 2** | Apply numerical differentiation and integration for electrical engineering applications |
| **CO 3** | Apply and analyze numerical techniques for solution to differential equation of dynamical systems |
| **CO 4** | Formulate optimization problems and identify a suitable method to solve the same |
| **CO 5** | Solve optimization problems in Electrical Engineering using appropriate optimization techniques |

**Mapping of course outcomes with program outcomes**

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

**Assessment Pattern**

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

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern: 40 marks**

Micro project/Course based project : 20 marks
Course based task/Seminar/Quiz : 10 marks
Test paper, 1 no. : 10 marks
Test paper shall include minimum 80% of the syllabus.

The project shall be done individually. Group projects not permitted.

**End Semester Examination Pattern:** 60 marks

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

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

## Model Question Paper

**SLOT A**

**APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY**
**SECOND SEMESTER M.TECH DEGREE EXAMINATION**
**MONTH &YEAR**
Course code: **222TEE100**
Course Name: **Computational Techniques in Electrical Engineering**

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

**PART A**

**Answer all Questions. Each question carries 5 Marks**

1 What is condition number of a matrix. Use condition number to check whether the following matrix is ill-conditioned.

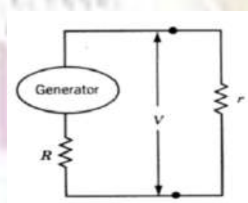
$$A = \begin{bmatrix} 1 & 1/2 & 1/3 \\ 1/2 & 1/3 & 1/4 \\ 1/3 & 1/4 & 1/5 \end{bmatrix}$$

2 Given the points $(0,0), \left(\frac{\pi}{2}, 1\right), (\pi, 0)$ satisfying the function $y = sin\ sin\ x\ (0 \leq x \leq \pi)$, determine the value of $y(\frac{\pi}{6})$ using the cubic spline approximation.

3 Solve the boundary value problem defined below using finite difference method. Compare the solution obtained at y(0.5) with the exact value for h=0.5 and h=0.25.

$$y'' - y = 0, \quad y(0) = 0, y(1) = 1$$

4 An electric generator has an internal resistance of R ohms and develops an open circuit voltage of V volts. Find the value of the load resistance r for which power delivered by the generator will be a maximum. *(Represent the problem as an optimization problem and solve for maximum power.)*




Electric generator with load

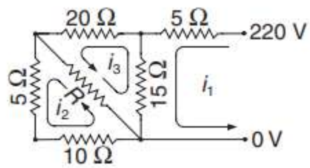
5 State the necessary and sufficient condition for existence of maximum or minimum for a multivariable objective function with constraints.

**PART B**

**Answer any 5 Questions. Each question carries 7 Marks**

6 The electrical network shown can be viewed as consisting of three loops. Apply Kirchoff's law to each loop yields and formulate the system as a classical linear algebraic

system. Compute the loop currents $i_1$, $i_2$ and $i_3$ using LU factorization method, for $R = 10\ \Omega$.




7 Find the zero of y(x) from the following data:

| $x$ | 0 | 0.5 | 1 | 1.5 | 2 | 2.5 | 3 |
|---|---|---|---|---|---|---|---|
| $y$ | 1.8421 | 2.4694 | 2.4921 | 1.9047 | 0.8509 | −0.4112 | −1.5727 |

Use Lagrange's interpolation over (a) three; and (b) four nearest-neighbor data points.

8 A second order system is defined by:

$$y'' = -\frac{19}{4}y - 10y', \quad y(0) = -9, y'(0) = 0$$

a. Find the analytical solution for the above system using the eigenvalues of the system
b. Show from (a) that the system is moderately stiff and estimate $\boldsymbol{h_{max}}$, the largest value of $\boldsymbol{h}$ for which the Runge–Kutta method would be stable.
c. Confirm the estimate by computing y(1) with h ≈ hmax/2 and h ≈ 2 hmax.

9 Faraday's law characterizes the voltage drop across an inductor as $V_L = L\frac{di}{dt}$, where $V_L$ is the voltage drop (V), ***L*** is the inductance (in Henrys (H)), ***i*** is the current (in Amps), and ***t*** is the time (in secs). Determine the voltage drop as a function of time from the following data for an inductance of *4 H*.

| Time, t (secs) | 0 | 0.1 | 0.2 | 0.3 | 0.5 | 0.7 |
|---|---|---|---|---|---|---|
| Current, i (Amps) | 0 | 0.1 | 0.32 | 0.56 | 0.84 | 2.0 |

10 Is this a linear or nonlinear programming problem?
Maximize $Z = 3x_1^2 - 2x_2$, subject to the constraints:

$$2x_1 + x_2 = 4$$
$$x_1^2 + x_2^2 \leq 40$$
$$x_1, x_2 \geq 0 \quad \text{and are integers.}$$

Solve this problem by a suitable classical method.

11 Minimize $f(x_1, x_2) = x_1 - x_2 + 2x_1^2 + 2x_1x_2 + x_2^2$ from the starting point $X_1 = \{0, 0\}$ using Powell's method.

12 Minimize the function given below using Univariate method method taking $X_1 = \{1, 1\}$ as the starting point.

$$f(x_1, x_2) = 2x_1^2 - x_1x_2 + 3x_2^2$$

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**SYLLABUS**

**Module 1**

**Systems of Linear Algebraic Equations***:* Uniqueness of Solution, Ill conditioning and norms**;** Methods of Solution: Gaussian elimination – LU factorization – Matrix inversion – Gauss-Seidel iteration – least squares method**;** Eigenvalue problems - Power method for eigenvalues – Tridiagonalization and QR factorization

**Module 2**

**Interpolation and Curve Fitting***:* Lagrange's Method, Newton's Method, Cubic Spline**;** Least-Squares Fit, Weighting of Data - Weighted linear regression**;** Roots of Equations: Newton–Raphson Method for systems of equations**;** Numerical differentiation - finite difference and first central difference approximations**;** Numerical integration - trapezoidal and Simpson's rule

**Module 3**

**Solution to differential equations***:* Initial Value Problems - Taylor Series Method, Euler Method, Runge–Kutta Methods-Second-Order and Fourth Order; Stability and Stiffness;

**Two-Point Boundary Value Problems***:* Shooting Method and finite difference method (Concept only)

**Case Study***:* MATLAB/C/ Python programming for solution to differential equations. Two-Point Boundary Value Problems - Shooting Method (Demo/Assignment only)

**Module 4**

Optimization problem, Formulation of optimization problems - linear optimization - Review only.

**Classical Optimization Techniques** Single variable optimization, Multivariable optimization with equality constraints- Direct substitution, method of Lagrange multipliers, Multivariable optimization with equality constraints- Kuhn-Tucker conditions.

**Module 5**

**Non-linear Programming - Unconstrained Optimization Techniques:** Direct Search Methods: Random search methods, Grid search method, Univariate method, Hookes and Jeeves' method, Powell's method; Indirect Search Methods: Steepest descent method, Fletcher-Reeves method, Newton's method.
**Nonlinear Programming - Constrained Optimization Techniques** *(Concepts Only - not for evaluation in the end semester examination)***:** Direct search methods - Random search methods, Basic approach in methods of feasible directions, Zoutendijk's method of feasible directions,

Rosen's gradient projection method, Generalized Reduced gradient method, Sequential quadratic programming.

**Recent developments in optimization techniques** *(Concepts only - Not for evaluation in the end semester examination)*: Genetic Algorithm, Simulated Annealing, Neural Network based optimization, Particle Swarm Optimization, Ant colony Optimization.

**Case studies**- Power system optimization, Optimal control problem, Electrical machine design optimization, Optimal design of Power Electronic converter- **Assignment/Demo only**

References


1. Erwin Kreyszig, Advanced Engineering Mathematics 9th Edition, Wiley International Edition Press, Numerical Recipes for scientific computing.
2. Bhaskar Dasgupta, Applied Mathematical Methods, Pearson.
3. Arfken, Weber and Harris, Mathematical Methods for Physicists, A comprehensive guide, 7th Edition, Elsevier, 2013.
4. S.S. Sastry, Introductory methods of numerical analysis, Fifth edition, PHI.
5. Numerical methods in Engineering with MATLAB, Jaan Kiusalaas
6. Singiresu S Rao, *Engineering Optimization Theory and Practice*,5/e, John Wiley&Sons 2020.
7. Edwin K P Chong, Stanislaw H Zak, *An introduction to Optimization*, 2e, Wiley India.
8. Optimization in Electrical Engineering, Mohammad Fathi, Hassan Bevrani, Springer


## COURSE PLAN

| No | Topic | No. of Lectures |
|---|---|---|
| **1** | ***Systems of Linear Algebraic Equations*** | **9 hrs** |
| 1.1 | Uniqueness of Solution, Ill conditioning and norms | 1 |
| 1.2 | Methods of Solution: Gaussian elimination – LU factorization – Matrix inversion | 3 |
| 1.3 | Gauss-Seidel iteration – least squares method | 2 |
| 1.4 | Eigenvalue problems - Power method for eigenvalues – Tridiagonalization and QR factorization | 3 |
| **2** | ***Interpolation and Curve Fitting*** | **8 hrs** |
| 2.1 | Lagrange's Method, Newton's Method, Cubic Spline**;** Least-Squares Fit | 3 |
| 2.2 | Weighting of Data - Weighted linear regression | 1 |

| | | |
|---|---|---|
| 2.3 | Roots of Equations: Newton–Raphson Method for systems of equations | 1 |
| 2.4 | Numerical differentiation - finite difference and first central difference approximations | 2 |
| 2.5 | Numerical integration - trapezoidal and Simpson's rule | 1 |
| **3** | ***Solution to differential equations*** | **7 hrs** |
| 3.1 | Initial Value Problems - Taylor Series Method | 1 |
| 3.2 | Euler Method | 1 |
| 3.3 | Runge–Kutta Methods - Second-Order and Fourth Order | 2 |
| 3.4 | Stability and Stiffness. | 1 |
| 3.5 | *Two-Point Boundary Value Problems:* Shooting Method and finite difference method (Concept only)<br><br>*Case Study:* Two-Point Boundary Value Problems - Shooting Method (Demo/Assignment only) | 2 |
| **4** | ***Formulation of Optimization problems and its solutions using classical methods*** | **7 hrs** |
| 4.1 | Optimization problem, Formulation of optimization problems - linear optimization - Review only. | 1 |
| 4.2 | Constrained Linear Optimization- Single variable optimization | 1 |
| 4.3 | Multivariable optimization - Direct substitution | 1 |
| 4.4 | Method of Lagrange multiplier, Necessary and sufficient conditions - Problems | 2 |
| 4.5 | Equality and inequality constraints, Kuhn -Tucker conditions (*both linear and nonlinear)* – Problems | 2 |
| **5** | ***Nonlinear - Unconstrained and constrained Optimization Techniques*** | **9 hrs** |
| 5.1 | Nonlinear Optimization problem - Unconstrained and Constrained problems | 1 |
| 5.2 | Unconstrained Problems: Direct search methods - Random search-pattern search - Grid Search methods. *(Concepts only for Constrained Optimization.)* | 2 |

| | | |
|---|---|---|
| 5.3 | Unconstrained - Univariate method, Hookes and Jeeves' method, Powell's method. | 2 |
| 5.4 | Indirect search methods: Descent Methods-Steepest descent, conjugate gradient, Fletcher- Reeves method. | 2 |
| 5.5 | *(Constrained Optimization - Concepts only - Not for evaluation)* Zoutendijk's method of feasible directions, Rosen's gradient projection method, Generalized Reduced gradient method, Sequential quadratic programming. | 2 |

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

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

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

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

**Mapping of course outcomes with program outcomes**

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

**Assessment Pattern**

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

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

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

**Continuous Internal Evaluation: 40 marks**

Micro project/Course based project: 20 marks

Course based task/Seminar/Quiz: 10 marks

Test paper, 1 no: 10 marks

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

**End Semester Examination: 60 marks**

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

**Model Question paper**

QP CODE:

Reg. No:______________ Name:________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY SECOND SEMESTER
M.TECH DEGREE EXAMINATION, MONTH & YEAR
Course Code: 222TEE002
Course Name: POWER SYSTEM OPERATION AND CONTROL

Max. Marks: 60 Duration: 2.5 Hrs

**PART A**

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

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

**PART B**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**Syllabus and Course Plan**

**Syllabus**

**Module 1 (8 Hours)**

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

**Module 2 (8 Hours)**

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

**Module 3 (8 Hours)**

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

**Module 4 ( 8 Hours)**

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

**Module 5 (8 Hours)**

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

**Course Plan**

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

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

**Text Books**

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

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

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

**Reference Books**

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

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

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

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

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

# PROGRAM ELECTIVE 3

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

**Preamble: Nil**

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

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

**Mapping of course outcomes with program outcomes**

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

**Assessment Pattern**

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

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern:**

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

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

Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

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

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

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

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

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

**Model Question Paper**

**Pages** **SLOT**

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

**STREAM:**

**221EIA002- EMBEDDED SYSTEMS AND APPLICATIONS**

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

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

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

**Syllabus**

**Module 1**

**Embedded System Organization**

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

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

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

**Module 2**

**Embedded Programming Concepts and RTOS**

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

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

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

**Module 3**

**Architecture and Programming of ARM**

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

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

**Module 4**

**On Chip Peripherals and Interfacing Lpc2148**

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

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

**Module 5**

**Embedded Control Applications -Case Studies**

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

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

Course Project: Develop an embedded control application using ARM Platform

**Course Plan**

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

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

**Reference Books**


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

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

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

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

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

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

**Preamble:**

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

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

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

**Mapping of course outcomes with program outcomes**

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

**Assessment Pattern**

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

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern:**

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

Preparing a review article based on peer reviewed

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

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

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

**End Semester Examination Pattern:**

*End Semester Examination: **60 marks***

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

**Model Question paper**

QP CODE:

Reg. No:_______________ Name:_________________

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

**Course Code: 222EEE013**

**Course Name: POWER CONVERSION TECHNIQUES IN POWER SYSTEMS**

Max. Marks: 60 Duration: 2.5 Hrs

**PART A**

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

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

**PART B**

***Answer any Five full questions. Each question carries 7 marks***

6. a) Derive the expression for the output voltage of flyback converter operating in continuous conduction mode with circuit diagram and necessary waveforms. (4)

   b) A single-phase full-wave ac voltage controller feeds a load of R = 20Ω with an input voltage of 230 V, 50 Hz. Firing angle for both the thyristors is 45°. Calculate (a) rms value of output voltage (b) load power and input pf (3)

7. With circuit diagram and waveforms, explain two stage sequence control of single-phase ac voltage controllers with R load. (7)
8. With circuit diagram and waveforms, explain the three-phase VSI in 180˚ conduction mode with R load. Derive the expression for fundamental voltages. (7)
9. Explain space vector modulation for inverters. Derive the expression to calculate dwell times. (7)

| | | |
|---|---|---|
| 10. | With neat circuit diagram and waveforms, explain the operation of single phase auto-sequential commutated CSI feeding pure inductive load. | (7) |
| 11. | a) Draw the circuit diagram and waveforms of full bridge series resonant inverter with unidirectional switches. Explain its principle of operation. | (4) |
| | b) Compare ZVS and ZCS resonant converters. | (3) |
| 12. | a) Explain the principle of operation of a cascaded Multilevel Inverter with a neat circuit diagram. | (4) |
| | b) Draw the circuit diagram of bidirectional inverter for PV system and explain its operation. | (3) |

**Syllabus**

**Module 1 (8 Hours):**

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

**Module 2 (9 Hours):**

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

**Module 3 (7 Hours):**

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

**Module 4 (8 Hours):**

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

**Module 5 (8 Hours):**

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

**Course Plan**

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

**Text Books**


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


**Reference Books**


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


APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY KTU Estd. 2014

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 222EEE027 | MODELING AND SIMULATION OF POWER ELECTRONIC SYSTEMS | Program Elective 3 | 3 | 0 | 0 | 3 |

**Preamble:**

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

**Course Outcomes:**

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

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

**Mapping of course outcomes with program outcomes**

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

**Assessment Pattern**

| Bloom's Category | End Semester Examination |
|---|---|
| Apply | 50 |
| Analyse | 30 |
| Evaluate | 10 |
| Create | 10 |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern: 40 marks**

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

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

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

**Model Question paper**

**Model Question Paper**

**PAGES: 2**

**QP CODE:XXXXX** **Slot : E**

Reg.No:_____________ Name:

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**

**SECOND SEMESTER MTECH DEGREE EXAMINATION**

**MONTH & YEAR**

Course Code**: 222EEE027**

Course Name: MODELING AND SIMULATION OF POWER ELECTRONIC SYSTEMS

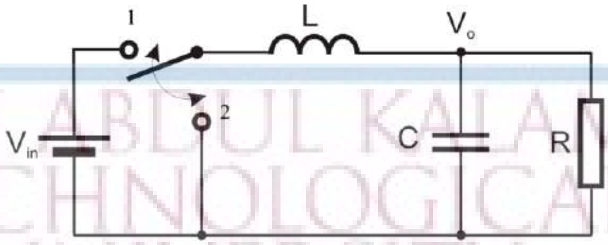
**Max. Marks: 60** **Duration: 2.5 Hours**

**PART A**

**Answer all questions**

**Each question carries 5 marks - 25 marks**

| | | | |
|---|---|---|---|
| 1 | | Derive the generic model of an ideal coil and develop a model block diagram of the same. | 5 |
| 2 | | Describe the concept of ITF and construct the model block diagram of a transformer with load alone using ITF | 5 |
| 3 | | Explain the algorithm for developing a switched model based on a switched network. | 5 |
| 4 | | Derive the switched model of a dc-dc buck converter. | 5 |
| 5 | | Explain the concept of averaging based on an averaged switch model. | 5 |
| | | **PART B**<br>**Answer any five full questions**<br>**7 marks each - 35 marks** | |
| 6 | | Describe the generic model of a coil with resistance. Draw the simulink based diagram to realise the above model for a coil with resistance 0.1 ohm and inductance10mH. | 7 |
| 7 | | Explain the model of a transformer with magnetizing inductance and thus develop a block diagram to realize the model | 7 |
| 8 | | Describe the representation of a four parameter transformer model and draw the simulink model of a four parameter transformer model. | 7 |
| 9 | | For a power electronic converter there are two switching states. In state 1, $v_O = V_{in}$ and in state 2, $v_O = V_{in}$, where $V_{in}$ is the dc input and $v_O$ is the output. Derive the switched model of the given converter. | 7 |

| | | | |
|---|---|---|---|
| 10 | | The switch in given circuit has two states 1 and 2. Out of total time period T, switch remains in state 1 & 2 for T/2 period each.<br><br><br>Develop the model of given circuit using switched modelling method and draw the equivalent circuit. | 7 |
| 11 | | Explain the model of a rectifier circuit and draw the equivalent circuit based on the model. | 7 |
| 12 | | In a power electronic converter, with a dc input of $V_{in}$ the inductor and capacitor voltage & current are respectively $v_L$ & $i_L$ and $v_C$ & $i_C$. The circuit equations for the on-time and off-time of the converter are as follows:<br>During $t_{on}$:<br>$V_i - \frac{di_L}{dt} - v_C = 0$ and $v_C + \frac{dv_C}{dt} - i_L = 0$<br>During $t_{off}$:<br>$v_C + \frac{di_L}{dt} = 0$ and $i_L - v_C - \frac{dv_C}{dt} = 0$<br>Develop the state space average model the converter and draw the equivalent circuit. | 7 |

**Syllabus**

**Module 1 (7 hours):**

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

*Assignment: Realization of inductor models using Simulink*

**Module 2 (8 hours):**

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

**Module 3 (10 hours):**

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

*Assignment: Realization of DC-AC inverter models using Simulink*

**Module 4 (10 hours):**

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

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

**Module 5 (8 hours):**

State space Modeling and Simulation of DC-DC Converters:Average State-space modeling: Linear circuits – Averaged model of switch;State-space modeling of DC-DC converters: Buck, boost, buck-boost converters; Small signal modeling and transfer function – Small signal Model of buck converter.

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

**Course Plan**

| No | Topic | No. of Lectures |
|---|---|---|
| 1 | **Modeling of Simple Electro-magnetic Circuits:** | |
| 1.1 | Generic model of linear inductance (ideal coil), transient response. | 1 |
| 1.2 | Block diagram representation of linear inductance model with excitation function. | 1 |
| 1.3 | Generic model of linear inductance with coil resistance | 2 |
| 1.4 | Block diagram representation of model of linear inductance with resistance and excitation function, incorporation of magnetic saturation problem, Block diagram representation of non-linear inductance model with sinusoidal excitation function. | 2 |
| 1.5 | *Assignment: Realization of inductor models using Simulink* | 1 |
| 2 | **Modeling of Transformer:** | |
| 2.1 | Concept of ideal transformer (ITF), Generic models of ITF, Generic model of transformer with load, | 3 |
| 2.2 | Generic model of transformer with load and finite *Lm*, Block diagram representation of transformer model with load and finite *Lm*. | 2 |
| 2.3 | Generic representation of transformer with magnetizing and leakage inductance, Generic representation of a four parameter transformer model, Block diagram representation of a four parameter transformer model. | 3 |
| 3 | **Modeling of DC & AC Machines:** | |
| 3.1 | Modeling of DC Motor-Equivalent circuit of DC motor, Model equations. Block diagram representation of DC Motor model. | 3 |
| 3.2 | Modeling of AC Machine -Concept of IRTF model module- model of induction motor using universal IRTF/ITF modules | 3 |
| 3.3 | Switched Models -Concept of switched models- Algorithms to develop switched model; Modeling of single- phase DC-AC inverter using switched model. | 3 |
| 3.4 | *Assignment: Realization of DC-AC inverter models using Simulink* | 1 |
| 4 | **Modeling of DC-DC converters based on Switched Model:** | |
| 4.1 | Derivation of switched model for a dc-dc buck converter in continuous conduction mode- Block diagram representation of dc-dc buck converter using switched model | 3 |

| | | |
|---|---|---|
| 4.2 | Switched model for a dc-dc boost converter in continuous conduction mode and dis-continuous conduction mode-Block diagram representation of dc-dc boost converter using switched model | 3 |
| 4.3 | Modeling of AC-DC rectifier using switched model | 3 |
| 4.4 | *Assignment: Dynamic behaviour of the switched model of the ideal buck and boost converter using switched model* | 1 |
| 5 | **State space Modeling and Simulation of DC-DC Converters** | |
| 5.1 | Average State-space modeling: Linear circuits – Averaged model of switch | 3 |
| 5.2 | State-space modeling of DC-DC converters: Buck, boost, buck-boost converters. | 2 |
| 5.3 | Small signal modeling and transfer function – Small signal Model of buck converter | 2 |
| 5.4 | *Simulink Assignment -Realization of DC-DC converter models using State-space model* | 1 |

**Text Books**

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

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

**References Books**

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

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

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

**Course Outcomes:**

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

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

**Mapping of course outcomes with program outcomes**

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

**Assessment Pattern**

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

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern:**

Continuous Internal Evaluation: 40 marks

Preparing a review article based on peer reviewed Original publications

(minimum 10 Publications shall be referred) : 15 marks

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

Test paper, 1 no. : 10 marks

(Test paper shall include minimum 80% )

**End Semester Examination Pattern:**

End Semester Examination: 60 marks

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

**Model Question Paper**

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

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

Course Code**: 222EEE015**

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

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

**PART A**

**Answer all questions**

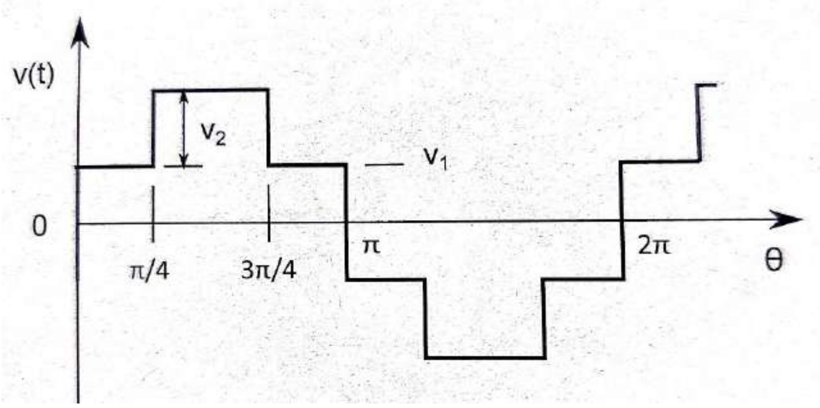
**Answer all Questions. Each question carries 5 Marks**

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

**PART B**

**Answer any 5 Questions. Each question carries 7 Marks**

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




(i) Evaluate the ratio ($V_1/V_2$) so that the inverter output voltage is free from 3rd harmonic content.

(ii) Evaluate $V_1$ if the rms value of output voltage is 230 V.

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

## Syllabus

**Module-1 ( 7 hrs.)**

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

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

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

**Purpose of Pulse-width modulation:**

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

**Module-2 ( 8 hrs.)**

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

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

**Sinusoidal pulse width modulation (SPWM):**

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

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

*MATLAB Simulation- Sine PWM controlled Voltage source inverter*

**Module-3 (8 hrs.)**

**Space vector PWM (SVPWM):**

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

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

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

**Module-4 (12 hrs.)**

**Analysis of line current ripple:**

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

**Analysis of dc link current:**

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

**Analysis of torque ripple:**

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

**Inverter loss:**

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

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

**Overmodulation:**

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

**Module-5 ( 5 hrs.)**

**Multilevel inverter (MLI):**

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

**PWM schemes for multilevel inverter:**

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

*MATLAB Simulation- Multi-level inverter operated with SVPWM.*

**Course Plan**

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

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

**Reference Books**


1. Dr. G. Narayanan, IISc, Bangalore, NPTEL Online Video course on “Pulse width Modulation for Power Electronic Converters” 2016.

2. D Grahame Holmes, Thomas A Lipo, Pulse Width Modulation for Power Converters: Principles and Practice, IEEE Press

3. Mohan, Undeland and Robbins, “Power Electronics: Converter, Applications and Design”, Wiley India, 2011.

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

5. Bin WU, High Power Converters and AC drives, John Wiley

6. M H Rashid (Ed), Power Electronics Handbook, Academic Press

7. Haitham Abu-Rub, Atif Iqbal, JaroslawGuzinski , “High Performance Control of AC Drives with Matlab/Simulink Models”, John Wiley and Sons Inc., 2012.

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

**Preamble: Nil**

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

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

**Mapping of course outcomes with program outcomes**

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

**Assessment Pattern**

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

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern: 40 marks**

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

Test paper shall include minimum 80% of the syllabus.

**End Semester Examination Pattern: 60 marks**

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

**Model Question paper**

Reg No.:_______________ Name:___________________________

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**
**Second Semester M.Tech Degree (R) Examination Month & Year**

**222EEE024 HYBRID & ELECTRIC VEHICLES**

Max. Marks: 60 Duration: 2.5 Hours

**Part A** Marks
(Answer all questions)

| | | |
|---|---|---|
| 1. | Compare conventional vehicle with hybrid-electric vehicle | [5] |
| 2. | Describe the factors affecting the performance of batteries used in Evs | [5] |
| 3 | A PM brushless DC motor has a torque constant of 0.12 Nm/A referred to the DC supply. Estimate the no load speed in RPM when connected to a 48V DC supply | [5] |
| 4. | Describe about direct measurement of SoC in battery | [5] |
| 5. | Describe rolling resistance and aerodynamic drag in vehicles | [5] |

**Part B**
(Answer any five questions)

| | | |
|---|---|---|
| 6 | State and explain the dynamic equation of vehicle motion | [7] |
| 7 | Explain the different power flow control modes of a typical parallel hybrid system with the help of block diagrams. | [7] |
| 8 | Draw three different configurations of drivetrains in electric vehicles. Briefly explain each configuration. | [7] |
| 9 | Describe the different battery charging modes? Compare them in detail. | [7] |
| 10. | An electric vehicle has the following parameters: | [7] |

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

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

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

| | | |
|---|---|---|
| 11 | Describe in detail about the electrical and mechanical constraints to be considered while sizing an electrical machine for an EV | [7] |
| 12 | A 460V, 60 Hz, six pole, 1176 rpm, Y-connected induction motor has the following parameters referred to the stator at rated condition.<br>The motor is fed by a six-step inverter The inverter is fed from a battery pac through DC/DC converter The battery pack voltage is 12V, Neglecting all losses,<br>(a) Determine the output of DC/DC converter<br>(b) Mention the type of the converter and its conversion ratio | [7] |

## Syllabus

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

**Course Plan**

| No | Topic | No. of Lectures |
|---|---|---|
| **1** | **Introduction to Hybrid & Electric Vehicles** | **(8 hours)** |
| 1.1 | History of hybrid & electric vehicles, social and environmental importance of hybrid & electric vehicles, Impact of modern drive-trains on energy supplies | 2 |
| 1.2 | Conventional vehicles: Basics of vehicle performance, vehicle power source characterization | 1 |
| 1.3 | Transmission characteristics, mathematical models to describe vehicle performance | 4 |
| 1.4 | Drive cycles an their impact on vehicle operation | 1 |
| **2** | **Hybrid Electric Drive-trains** | **(8 hours)** |
| 2.1 | Basic concepts of hybrid traction, introduction to various hybrid drive-train topologies | 1 |
| 2.2 | Power flow control in hybrid drive-train topologies, fuel efficiency analysis | 2 |
| 2.3 | Electric drive-trains: Basic concepts of electric traction | 1 |
| 2.4 | Introduction to various electric drive-train topologies, Power flow control in electric drive-train topologies | 4 |
| **3** | **Electric Propulsion System** | **(8 hours)** |
| 3.1 | Introduction to electric components used in hybrid an electric vehicles, Desired features for an EV motor | 1 |
| 3.2 | Introduction to various EV motors, T-w characteristics | 1 |
| 3.3 | Configuration and control of Brushless DC Motor drives | 1 |
| 3.4 | Configuration and control of Permanent Magnet Synchronous Motor drives | 2 |
| 3.5 | Configuration and control of Induction Motor drives, Configuration and Control of Switched Reluctance Motor drives | 2 |
| 3.6 | Protection schemes for power converters | 1 |
| **4** | **Energy Storage Systems** | **(8 hours)** |
| 4.1 | Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis, SoC estimation | 2 |
| 4.2 | Other advanced storage topologies - Supercapacitor based system, Fuel cell based system, Fly wheel based system | 2 |
| 4.3 | Hybridization of different energy storage devices | 1 |
| 4.4 | Introduction to Energy Management Strategies in Hybrid and Electric vehicles, classification and comparison of various strategies | 2 |
| 4.6 | Implementation issues for energy management strategies | 1 |
| **5** | **Sizing of Drive System, In-vehicle Communication** | **(8 hours)** |
| 5.1 | Matching the electrical machine and IC engine, Sizing of propulsion motor | 2 |
| 5.2 | Sizing of power electronic components, Selection of energy storage technology | 1 |

| | | |
|---|---|---|
| 5.3 | Case studies - Design of Hybrid Electric Vehicle, Design of Battery Electric Vehicle | 3 |
| 5.4 | Automotive Sensors and Actuators, Communication between major components, In-vehicle networks - CAN | 3 |

**Reference Books**


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

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

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

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

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

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 222EEE017 | APPLICATION OF AI IN POWER SYSTEMS | Program Elective 3 | 3 | 0 | 0 | 3 |

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

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

| | |
|---|---|
| **CO1** | Detail various ANN configurations. |
| **CO2** | Develop fuzzy logic controller for power system applications. |
| **CO3** | Apply Evolutionary algorithms in electrical engineering problems |
| **CO4** | Apply Hybrid intelligent techniques in simple optimisation problems. |
| **CO5** | Demonstrate application of swarm intelligence based AI techniques in power system. |

**Mapping of course outcomes with program outcomes**

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

**Assessment Pattern**

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

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern:**

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

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

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

**End Semester Examination Pattern:**

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

**Model Question paper**

**QP CODE:** **PAGES: 2**

**Reg No:_______________** **Name:_________________**

# APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

## SECOND SEMESTER M.TECH DEGREE EXAMINATION, MONTH & YEAR

## Course Code: 222EEE017

## Course name: APPLICATION OF AI IN POWER SYSTEMS

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

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

1) List down the characteristics of intelligent agent.

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

3) Two fuzzy sets P and Q are defined on $x \epsilon X$ as follows.

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

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

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

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

a. Evaporation

b. Transition Probability

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

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

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

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

x1 = 6 5 4 1 3 5 3 2

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

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

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

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

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

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

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

**Course Plan**

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

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

**Text Books**

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

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

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

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

**References**

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

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

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

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

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

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

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

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

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

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

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

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

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

14. D.E.Goldberg, “Genetic Algorithms,”, Addison Wesley 1999.

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

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

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

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

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

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

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

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
KTU
Estd.
2014

# PROGRAM ELECTIVE 4

APJ ABDUL KALAM
TECHNOLOGICAL
UNIVERSITY
KTU
Estd.
2014

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

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

**Preamble: Nil**

**Course Outcomes:**

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

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

**Mapping of course outcomes with program outcomes**

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

**Assessment Pattern**

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

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation: 40 marks**

Preparing a review article based on peer reviewed

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

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

Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

**End Semester Examination: 60 marks**

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

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

**Model Question paper**

**QP Code:**

| | | |
|---|---|---|
| **Name:** | | **Reg No:** |

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

**Course Code: 222EEE019**

**Course Name: Power System Automation**

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

PART A (5 x 5 = 25 Marks)

Answer all Questions. Each question carries 5 Marks

| **Q.no.** | **Module 1** | **Marks** |
|---|---|---|
| **1** | Mention different steps involved in SCADA system | **5** |
| | **Module 2** | |
| **2** | Analyse the functions of modern IED in SCADA system | **5** |
| | **Module 3** | |
| **3** | Mention main features of IEC 61850 | **5** |
| | **Module 4** | |
| **4** | Discuss the need of substation automation automation in present scenario | **5** |
| | **Module 5** | |
| **5** | Describe real time automatic generation control in SCADA system | **5** |
| | | |
| | PART B (7 x 5 = 35 Marks)<br>Answer any five full questions. Each question carries 7 Marks | |

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

**Syllabus**

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

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

**Course Plan**

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

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

**Reference Books**


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

## SYLLABUS

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

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

**Course Outcomes:**

After the completion of the course the student will be able

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

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

**Mapping of course outcomes with program outcomes**

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

**Assessment Pattern**

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

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern:**

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

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

Test paper, 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus.

**End Semester Examination Pattern:**

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

Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry7 marks.

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

**Model Question Paper**

**QP CODE:** PAGES: 2

Reg.No:______________ Name:

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**

**SECOND SEMESTER M. TECH DEGREE EXAMINATION**

**MONTH & YEAR**

Course Code**: 222EEE016**

Course Name: **NONLINEAR CONTROL SYSTEMS**

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

**PART A**

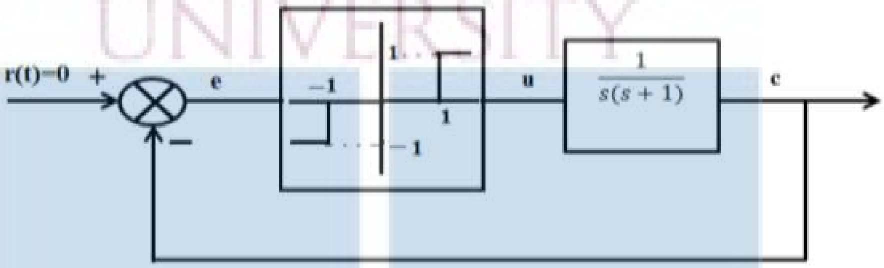
**Answer all questions**

**Each question carries 5 marks**

| | | | |
|---|---|---|---|
| 1 | | What are singular points? Classify singular points based on Eigen values with necessary equations and phase trajectories. | 5 |
| 2 | | State and prove the theorem on continuity of solutions in terms of initial states and parameters. | 5 |
| 3 | | Check the stability of the following system using Lyapunov Stability analysis<br>$\dot{x}_1 = x_1(k^2 - x_1{}^2 - x_2{}^2) + x_2\,(k^2 + x_1{}^2 + x_2{}^2)$<br>$\dot{x}_2 = -x_1(k^2 + x_1{}^2 + x_2{}^2) + x_2\,(k^2 - x_1{}^2 - x_2{}^2)$<br>When a) k=0 b) $k \neq 0$ | 5 |
| 4 | | Explain loop transformation applied to circle criterion. | 5 |
| 5 | | Write notes on Integral control via linearization. | 5 |

**PART B**

**Answer any 5 full questions**

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

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

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY Estd. 2014

**Syllabus**

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

**Course Plan**

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

**Text Book:**

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

**References:**

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

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

**Preamble:**

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

**Course Outcomes:**

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

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

**Mapping of course outcomes with program outcomes**

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

**Assessment Pattern**

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

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern:**

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

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

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

Test paper shall include minimum 80% of the syllabus.
Note: SCILAB/MATLAB based simulation work can also be considered for course based task.

**End Semester Examination Pattern:**

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

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

**Model Question paper**

**D**

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**

SECOND SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 20XX

ELECTRICAL AND ELECTRONICS ENGINEERING

Streams: POWER SYSTEMS

**222EEE021 DISTRIBUTION SYSTEM ANALYSIS**

Max. Marks: 60 Duration: 2.5 Hours

**Part A**

**Answer ALL Questions**

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

(5x5=25 marks)

**Part B**

**Answer any FIVE full Questions**

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

**Syllabus**

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

**Course Plan**

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

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

**Reference Books**


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

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

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 222EEE026 | ENERGY STORAGE SYSTEMS | Program Elective-4 | 3 | 0 | 0 | 3 |

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

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

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

**Mapping of course outcomes with program outcomes**

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

**Assessment Pattern**

| Bloom's Category | End Semester Examination |
|---|---|
| Apply | 40% |
| Analyse | 40% |

| | |
|---|---|
| Evaluate | 20% |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern:**

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

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

Test paper, 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus.

**End Semester Examination Pattern:**
The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.
Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry7 marks.
Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

**Model Question paper**

**SLOT D**

QP CODE: PAGES: 2

Reg.No:______________ Name:______________

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**

**FIRST SEMESTER M.TECH DEGREE EXAMINATION,**

**MONTH & YEAR**

**Course Code: 222EEE026**

**Course Name: Energy Storage Systems**

Max. Marks: 100 Duration: 3 Hours

**PART A (5 x 5 = 25 Marks)**

**Answer all Questions. Each question carries 5 Marks**

1. Compare the different energy storage techniques citing applications for each type.

2. A battery has capacity of 4000mAh and a C rating of 10C, then calculate the maximum current the battery can deliver.

3.Compare the characteristics of Ultra Capacitors with batteries.

4. Discuss about the major requirements for an electrolyte in a fuel cell.

5. Illustrate the technical requirements for energy storage systems in micro-grids and smart grids?

**PART B (5 x 7 = 35 Marks)**

**Answer any five Questions. Each question carries 7 Marks**

6. Explain the different types of chemical energy storage systems.

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

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

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

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

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

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

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

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

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

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

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

**Syllabus:**

**Module 1 (6 Hrs)**

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

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

**Module 2 (11 Hrs)**

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

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

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

**Module 3 (7 Hrs)**

**Magnetic and Electric Energy Storage Systems:**

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

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

**Module 4 (10 Hrs)**

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

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

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

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

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

**Module 5 (6 Hrs)**

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

**Course Plan:**

| No | Topic | No. of Lectures |
|---|---|---|
| 1 | **Module 1 (6 Hrs)** | |
| 1.1 | Need of energy storage, different types of energy storage.<br>Potential energy: Pumped hydro storage.<br>Compressed gas system: Compressed air energy storage. | 1 |
| 1.2 | Kinetic energy: Flywheel storage operation, principles of flywheels, power capacity of flywheel systems, flywheel technologies. | 1 |
| 1.3 | Fossil fuels and synthetic fuels, Solar ponds for energy storage | 1 |
| 1.4 | Electrical and magnetic energy storage: Capacitors, electromagnets. | 1 |
| 1.5 | Chemical energy storage: Thermo-chemical, photo-chemical, bio-chemical, electro-chemical systems. | 1 |
| 1.6 | Comparison of energy storage technologies, Hybridization of energy storages. | 1 |
| 2 | **Module 2 (11 Hrs)** | |

| | | |
|---|---|---|
| 2.1 | Fundamental concepts of batteries: Primary and Secondary batteries, Electrochemical reactions, Thermodynamic voltage, Battery Equivalent circuit. | 1 |
| 2.2 | Battery parameters - storage density, energy density, energy efficiency, charge efficiency, specific energy, specific power, state of charge (SoC), state of health (SoH), state of function (SoF), Measurement of battery performance. | 1 |
| 2.3 | Factors affecting battery cell life cycles - C rate, depth of discharge (DoD) | 1 |
| 2.4 | Battery Technologies: Lead-acid batteries, Nickel-based batteries- Nickel/iron, nickel/cadmium, nickel–metal hydride (Ni–MH), Applications. | 1 |
| 2.5 | Lithium-based batteries: Lithium–polymer (Li–P), lithium-ion (Li-Ion). | 1 |
| 2.6 | Lithium-Cobalt, Lithium Manganese Oxide, Lithium Iron Phosphate (LiFP) | 1 |
| 2.7 | Lithium Nickel Manganese Cobalt Oxide (NMC), Lithium Nickel Cobalt Aluminium Oxide (NCA), Lithium Titanate, Applications | 1 |
| 2.8 | Battery pack development process - Electrical design of battery pack, busbar design. | 2 |
| 2.9 | Battery cell testing, Testing standards, Safety issues. | 1 |
| 2.10 | Charging and discharging of a battery, Charge / Discharge characteristics. | 1 |
| 3 | **Module 3 (7 Hrs)** | |
| 3.1 | **Magnetic and Electric Energy Storage Systems:**<br>Superconducting magnetic energy storage (SMES) systems, Capacitors. | 2 |
| 3.2 | Ultra-capacitor: Basic principles, equivalent circuit. | 1 |
| 3.3 | Ultra-capacitor technologies: Electrochemical double layer capacitor (EDLC), principle of working, structure, performance and applications, | 2 |
| 3.4 | Role of activated carbon and carbon nano-tubes in performance enhancement. | 1 |

| | | |
|---|---|---|
| 3.5 | Comparison of Ultra-capacitor characteristics with batteries - applications | 1 |
| 4 | **Module 4 (10 Hrs)** | |
| 4.1 | **Fuel Cells:** Operating principle of fuel cells: Electrode potential and current–voltage curve | 1 |
| 4.2 | Fuel cell reactions with alkaline / acid / molten carbonate / ceramic electrolytes / Methanol fuel cells, Fuel cell system characteristics, Circuit model | 1 |
| 4.3 | Hydrogen as energy carrier, Hydrogen storage, Hydrogen production: Compressed hydrogen, cryogenic liquid hydrogen, metal hydrides. | 2 |
| 4.4 | Fuel cell technologies:, alkaline fuel cells (AFC), Phosphoric acid fuel cells (PAFC) | 1 |
| 4.5 | Molten carbonate fuel cells (MCFC), Solid oxide fuel cells (SOFC) | 1 |
| 4.6 | Non-hydrogen fuel cells, Direct methanol fuel cells (DMFC), Proton exchange membrane (PEM) fuel cells. | 1 |
| 4.7 | Rechargeable fuel cells, Applications | 1 |
| 4.8 | Hybrid fuel cell-battery systems, hybrid fuel cell-supercapacitor systems. | 2 |
| 5 | **Module 5 (6 Hrs)** | |
| 5.1 | Energy storage systems for electric vehicles: Mechanical, electrochemical, chemical, electrical and thermal storage systems. | 1 |
| 5.2 | Hybrid energy storage systems: Configurations and applications, Backup energy supply (PV array). | 1 |
| 5.3 | Standards for EV batteries: IS 17855: 2022 / ISO 12405-4: 2018. | 1 |
| 5.4 | Energy Storage in Micro-Grids and Smart Grids:<br><br>Technical requirements: Round-trip efficiency, response time, lifetime and cycling, sizing, operation and maintenance, use cases | 1 |
| 5.5 | Frequency regulation, renewable energy integration, peak shaving and load levelling. | 1 |

| | | |
|---|---|---|
| 5.6 | Energy management with storage systems, Battery SCADA, Enhancement of energy conversion efficiency by introducing energy storage. | 1 |

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**Text Books:**

[1] T R Crompton, “Battery Reference Book”, Reed Educational and Professional Publishing Ltd., 2000.
[2] James Larminie and John Lowry, “Electric Vehicle Technology Explained”, John Wiley & Sons Ltd., 2003.
[3] John Warner, “The Handbook of Lithium Ion Battery Pack Design”, Elsevier Inc., 2015.
[4] Aldo V Da Rosa, “Fundamentals of Renewable Energy Processes”, Elsevier Academic Press, 2005.

**References:**

[1] Handbook on Battery Energy Storage System, Asian Development Bank, December 2018.
[2] Iqbal Hussain, “Electric and Hybrid Vehicles – Design fundamentals”, CRC Press, 2021.
[3] Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay, Ali Emadi, “Modern Electric, Hybrid Electric, and Fuel Cell Vehicles”, CRC Press, 2005.
[4] Ali Emadi, “Handbook of Automotive Power Electronics and Motor Drives”, Taylor & Francis, 2005.
[5] C C Chan and K T Chau, “Modern Electric Vehicle Technology”, Oxford University Press, 2001.
[6] Ali Emadi, “Advance Electric Drive Vehicles”, CRC Press, 2015.
[7] NPTEL Lecture notes - “Introduction to Hybrid and Electric Vehicles - Module 9: Energy Storage” https: //nptel.ac.in/content/storage2/courses/108103009/download/M9.pdf
[8] NPTEL Video Lecture 03: “Supercapacitors” https://archive.nptel.ac.in/courses/113/105/113105102/
[9] NPTEL Video Lecture: Battery pack development, Part 2: https://www.youtube.com/watch?v=ArkO0u1Q3co

# INTERDISCIPLINARY ELECTIVE

| 222EEE070 | **Energy Efficiency in Electrical Engineering** | **CATEGORY** | **L** | **T** | **P** | **CREDIT** |
|---|---|---|---|---|---|---|
| | | Interdisciplinary Elective | 3 | 0 | 0 | 3 |

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

**Course Outcomes:**

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

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

**Mapping of course outcomes with program outcomes**

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

**Assessment Pattern**

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

**Mark distribution**

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

**Continuous Internal Evaluation Pattern:**

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

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

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

**End Semester Examination Pattern:**

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

**Model Question paper**

**QP CODE:** **PAGES: 2**

**Reg No:_____________** **Name:______________**

## APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

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

## Course Code:

## Course name: Energy Efficiency in Electrical Engineering

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

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

1) State the meaning and need of Energy Conservation.

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

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

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

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

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

6) Explain the impact of energy usage on climate.

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

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

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

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

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

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

12) Explain different energy efficient lighting control with features.

## Syllabus

**Module 1: Energy Scenario:**

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

**Module 2: Energy Efficiency in Electrical Supply System and Motors**

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

**Module 3: Energy Efficiency in Electrical Utilities**

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

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

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

**Module 5 :Energy Efficient Technologies in Electrical Systems**

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

**Course Plan**

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

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**Reference Books**

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

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

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

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

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

**Important Links:**

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

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

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

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

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

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

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

**Preamble:**

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

**Course Outcomes:**

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

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

**Mapping of course outcomes with program outcomes**

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

**Assessment Pattern**

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

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern:**

Preparing Review Article based on peer reviewed Original publications (Minimum 10 publications shall be referred) : 15 marks

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

Test paper, 1 nos : 10 marks

**End Semester Examination Pattern:**

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

**Model Question paper**

**APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY**

**SECOND SEMESTER M.TECH DEGREE EXAMINATION**

**MONTH &YEAR**

Course code: 222EEE071

Course Name: Electric charging Systems for Electric Vehicles

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

**PART A**

**(Answer all questions. Each question carries 5 marks)**

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

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

**PART –B**
**(Answer any five questions, each question carries 7 marks)**

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

**Syllabus**

**Module 1- AC-DC converters**

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

**Module 2- DC-DC converters**

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

**Module 3- Energy storage**

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

**Module 4- Charging infrastructure**

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

**Module 5- Charging Standards**

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

**COURSE PLAN**

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

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

**Text books:**


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

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

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

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

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

### Mapping of course outcomes with program outcomes

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

### Assessment Pattern

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

### Mark distribution

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

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

Test paper shall include minimum 80% of the syllabus.

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

**Model Question paper**

**QP Code:**
**Name:**
**Reg No:**

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

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

PART A (5 x 5 = 25 Marks)

Answer all Questions. Each question carries 5 Marks

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

## Module 5

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

PART B (7 x 5 = 35 Marks)

Answer any five full questions. Each question carries 7 Marks

**6 a.** Write the applications for the following solar radiation–measuring instruments: **2**

Pyrheliometer

Sunshine recorder

**b.** Draw the flowchart for an ANN model for estimation of solar irradiance using Backpropagation algorithm. **5**

**7.** A PV panel having an area of 1.5m2gives the following readings under standard test conditions. The short circuit current is 8A, the open circuit voltage is 40V, the voltage at peak power is36.5V and the current at peak power is 7A. The fill factor of the PV panel is found to be 0.72. Calculate the efficiency of the panel. **7**

**8.** Derive the expression for impedance seen by the solar cell utilizing the volt-sec and amp-sec balance concept, when a Buck Converter is used for MPPT operation. Sketch the operating region with Load line concept in I-V curve of Solar cell, while using Buck Converter for MPPT operation. **7**

**9 a.** The present cost of a solar panel is Rs 2000. If the interest rate is 8% and the inflation rate is 5% then how much must one save today in order to purchase the solar panel 5 years from now? **3**

**b** Explain the steps involved in design of standalone solar PV system **4**

**10** Draw the functional block diagram of a 3 phase grid connected Solar P V system under d-q frame control. Explain each section in details. **7**

**11.** Derive the expression for impedance seen by the solar cell utilizing the volt-sec and amp-sec balance concept, when a Buck Converter is used for MPPT operation. Sketch the operating region with Load line concept in I-V curve of Solar cell, while using Buck Converter for MPPT operation **7**

**12a.** What are the advantages of supercapacitors and fuel cells compared to conventional battery energy storage system. **4**

**b.** Explain Depth of Discharge, life cycle of battery and round-trip efficiency **3**

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

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

**Syllabus and Corse Plan**

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

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

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

**Text Books**


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


**References**


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

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

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

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

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

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

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

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

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

| COURSE CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 222PEE100 | MINI PROJECT | PROJECT | 0 | 0 | 4 | 2 |

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

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

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

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

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

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

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

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

**Mapping of course outcomes with program outcomes**

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

**Assessment Pattern**

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

**Continuous Internal Evaluation Pattern: 100 Marks**

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

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

**List of Experiments**

Part A: POWER SYSTEM SIMULATION EXPERIMENTS

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

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

Part B: POWER SYSTEM COMPONENT TESTING (Hardware experiments)

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

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

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

**Reference Books**


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

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
KTU
Estd.
2014

# SEMESTER III

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TECHNOLOGICAL
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KTU
Estd.
2014

**SEMESTER III**

| Slot | Course code | Courses | Marks | | L-T-P | Hours | Credit |
|---|---|---|---|---|---|---|---|
| | | | CIE | ESE | | | |
| TRACK 1 | | | | | | | |
| A* | 223MxxXXX | MOOC | To be completed successfully | | -- | -- | 2 |
| B | 223AGEXXX | Audit Course | 40 | 60 | 3-0-0 | 3 | - |
| C | 223Ixx100 | Internship | 50 | 50 | -- | -- | 3 |
| D | 223Pxx100 | Dissertation Phase 1 | 100 | -- | 0-0-17 | 17 | 11 |
| TRACK 2 | | | | | | | |
| A* | 223MxxXXX | MOOC | To be completed successfully | | -- | -- | 2 |
| B | 223AGEXXX | Audit Course | 40 | 60 | 3-0-0 | 3 | - |
| C | 223Ixx100 | Internship | 50 | 50 | --- | -- | 3 |
| D | 223Pxx001 | Research Project Phase1 | 100 | -- | 0-0-17 | 17 | 11 |
| **TOTAL** | | | **190** | **110** | | **20** | **16** |

**Teaching Assistance: 6 hours**

*MOOC Course to be successfully completed before the commencement of fourth semester (starting from semester 1).

## AUDIT COURSE

| AUDIT COURSE | | | | | | |
|---|---|---|---|---|---|---|
| **SLOT** | **SL NO** | **COURSE CODE** | **COURSE NAME** | **L-T-P** | **HOURS** | **CREDIT** |
| B | 1 | 223AGE100 | ACADEMIC WRITING | 3-0-0 | 3 | - |
| | 2 | 223AGE001 | ADVANCED ENGINEERING MATERIALS | 3-0-0 | 3 | - |
| | 3 | 223AGE002 | FORENSIC ENGINEERING | 3-0-0 | 3 | - |
| | 4 | 223AGE003 | DATA SCIENCE FOR ENGINEERS | 3-0-0 | 3 | - |
| | 5 | 223AGE004 | DESIGN THINKING | 3-0-0 | 3 | - |
| | 6 | 223AGE005 | FUNCTIONAL PROGRAMMING IN HASKELL | 3-0-0 | 3 | - |
| | 7 | 223AGE006 | FRENCH LANGUAGE (A1 LEVEL) | 3-0-0 | 3 | - |
| | 8 | 223AGE007 | GERMAN LANGUAGE (A1 LEVEL) | 3-0-0 | 3 | - |
| | 9 | 223AGE008 | JAPANESE LANGUAGE (N5 LEVEL) | 3-0-0 | 3 | - |
| | 10 | 223AGE009 | PRINCIPLES OF AUTOMATION | 3-0-0 | 3 | - |
| | 11 | 223AGE010 | REUSE AND RECYCLE TECHNOLOGY | 3-0-0 | 3 | - |
| | 12 | 223AGE011 | SYSTEM MODELING | 3-0-0 | 3 | - |
| | 13 | 223AGE012 | EXPERT SYSTEMS | 3-0-0 | 3 | - |

## MOOC COURSES

The MOOC course shall be considered only if it is conducted by the agencies namely AICTE/NPTEL/SWAYAM or NITTTR. The MOOC course should have a minimum duration of 8 weeks and the content of the syllabus shall be enough for at least 40 hours of teaching. The course should have a proctored/offline end semester examination. The students can do the MOOC according to their convenience, but shall complete it by third semester. The list of MOOC courses will be provided by the concerned BoS if at least 70% of the course content match with the area/stream of study. The course shall not be considered if its content has more than 50% of overlap with a core/elective course in the concerned discipline or with an open elective.

MOOC Course to be successfully completed before the commencement of fourth semester (starting from semester 1). A credit of 2 will be awarded to all students whoever successfully completes the MOOC course as per the evaluation pattern of the respective agency conducting the MOOC.

## TEMPLATE FOR SYLLABUS

| CODE 223AGE100 | ACADEMIC WRITING | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| | | AUDIT COURSE | 3 | 0 | 0 | NIL |

**Preamble:** Learning academic writing sharpens minds, teaches students how to communicate, and develops their thinking capacities and ability to understand others. Writing is thinking, and every student deserves to be a strong thinker. It can also make them think more carefully about what they write. Showing work to others can help to foster a better culture of learning and sharing among students. It also gives students a sense of how they are contributing to the body of work that makes up an academic subject.

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

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

| | |
|---|---|
| **CO 1** | Understand the principles of scientific/ academic writing |
| **CO 2** | Analyse the technique of scientific writing from the reader's perspective |
| **CO 3** | Apply the concepts of setting expectations and laying the progression tracks |
| **CO 4** | Evaluate the merits of a title, abstract , introduction, conclusion and structuring of a research paper |
| **CO 5** | Justify the need using a project proposal or a technical report |
| **CO 6** | Prepare a review paper, an extended abstract and a project proposal |

**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 | | 3 | 1 | | | | |
| CO 3 | | 3 | 1 | | | 2 | |
| CO 4 | | 3 | 1 | | | | |
| CO 5 | | 3 | 2 | 2 | | 2 | |
| CO 6 | 1 | 3 | 3 | 2 | | 2 | |

**Assessment Pattern**

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

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern: 40 marks**

Course based task : 15 marks
Seminar/Quiz : 15 marks
Test paper, 1 no. : 10 marks
Test paper shall include minimum 80% of the syllabus.

**End Semester Examination Pattern:** 60 marks

The examination will be conducted by the respective College. The examination willbe for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any Vive. Each question can carry 12 marks.

**Model Question paper**

| | | |
|---|---|---|
| | **SET1** | **Total Pages:** |
| Reg No.:_______________ | | Name:___________________________ |
| **APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**<br>THIRD SEMESTER M.TECH DEGREE EXAMINATION, MARCH 2024 | | |
| **Course Code: 223AGE100** | | |
| **Course Name: Academic Writing** | | |
| Max. Marks: 60 | | Duration: 2.5 Hours |
| ***Answer any five full questions, each carries 12 marks.*** | | |

| | | |
|---|---|---|
| 1 a) | Make clear-cut distinctions between 6 factors that take their toll on readers' memory. | 6 |
| 1 b) | How can you sustain the attention of the reader to ensure continuous reading? | 6 |
| 2 a) | What are the different methods by which you can create expectations in the reader? | 6 |
| 2 b) | Give an account of the topic and non-topic based progression schemes. | 6 |
| 3 a) | Bring out the differences between an abstract and the introduction of a research paper. | 8 |
| 3 b) | How are the title of the research paper and its structure related? | 4 |
| 4 | What are 7 principles for including visuals in your research paper. What are the recommended constituents of a conclusion segment of a research paper? | 12 |

| | | |
|---|---|---|
| 5 | Give a detailed description of the process and contents of a project proposal for funding. | 12 |
| 6 a) | What are the contexts recommended for choosing between active and passive voices in technical writing? | 8 |
| 6 b) | What are the different visual forms that are relevant in a research paper and how do you choose them? | 4 |
| 7 | Give the design of a research paper with the purposes each part serves. | 12 |
| | **** | |

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

**Syllabus:**

| **CODE** 223AGE100 | **ACADEMIC WRITING** | **Audit** |
|---|---|---|
| Module No. | Topics in a module | Hours |
| 1 | Fundamentals of Academic writing from a reader's perspective: acronyms, synonyms, pronouns, disconnected phrases, background ghettos, abusive detailing, cryptic captions, long sentences : all that take their toll on readers' memory. | 6 |
| 2 | Fluid reading & reading energy consumption: setting expectations and laying Progression tracks; Reading energy consumption | 6 |
| 3 | How to write the Title, abstract, introduction ; Structure the writing with headings & subheadings | 6 |
| 4 | Visuals: Resources, Skills, and Methods; Conclusion; References; Bibliography; Grammar in technical writing | 6 |
| 5 | Techniques of writing: An extended abstract, a project proposal, a research paper, a technical report. | 6 |

**Course Plan:**

| No | Topic | No. of Lectures |
|---|---|---|
| 1 | Fundamentals of Academic writing from a reader's perspective: acronyms, synonyms, pronouns, disconnected phrases, background ghettos, abusive detailing, cryptic captions, long sentences all take their toll on readers' memory. | |
| 1.1 | The Reading tool-kit to reduce memory required; reduce reading time | 1 |
| 1.2 | Acronyms, Pronouns, Synonyms; Background, broken couple, words overflow | 1 |
| 1.3 | Sustain attention: Keep the story moving forward; Twists, shouts, Pause to clarify, recreate suspense | 2 |

| | | |
|---|---|---|
| 1.4 | Keep the reader motivated: Fuel and meet Expectations; Bridge knowledge gap: ground level; Title words; Just In Time to local background | 2 |
| 2 | Fluid reading & reading energy consumption: setting expectations and laying Progression tracks; Reading energy consumption | |
| 2.1 | Setting expectations of the reader from Grammar, from theme | 1 |
| 2.2 | Progression tracks for fluid reading: Topic & stress; topic and non topic based progression tracks; pause in progression | 2 |
| 2.3 | Detection of sentence fluidity problems: No expectations/ Betrayed expectations | 2 |
| 2.4 | Controlling reading energy consumption: the energy bill; Energy fuelling stations: Pause | 1 |
| 3 | How to write the Title, abstract, introduction ; Structure the writing with headings & subheadings | |
| 3.1 | Title: Face of the paper: Techniques, Qualities & Purpose of title; Metrics | 1 |
| 3.2 | Abstract: Heart of the paper: 4 parts; coherence; tense of verbs, precision; purpose & qualities of the abstract; Metrics | 2 |
| 3.3 | Structure: Headings & sub-headings: Skeleton of the paper: principles for a good structure; Syntactic rules; Quality & Purpose of structures; Metrics | 1 |
| 3.4 | Introduction: Hands of the paper: Start, finish; scope, definitions; answers key reader questions; As a personal active story; Traps, qualities; Metrics | 2 |
| 4 | Visuals: Resources, Skills, and Methods; Conclusion; References; Bibliography; Grammar in technical writing | |
| 4.1 | Visuals as the voice of your paper: principles; purpose & qualities of visuals; metrics | 2 |
| 4.2 | Conclusion: contents; purpose, quality; metrics; Abstracts Vs. Conclusion; examples, counter-examples | 1 |
| 4.3 | References, Bibliography: Styles, punctuation marks, quotes, citations | 1 |
| 4.4 | Grammar in Technical writing: Articles, Syntax, Main and subordinate clauses; Active & passive voices; some commonly made mistakes in technical writing. | 2 |
| 5 | Techniques of writing: An extended abstract, a project proposal, a research paper, a technical report. | |
| 5.1 | Extended abstract: abstract and keywords, introduction and objective, method, findings and argument, conclusion and suggestions and references. | 1 |
| 5.2 | Project Proposal:Types, executive summary, background including status, objectives, solution, milestones, deliverables, timelines, resources, budgeting, conclusion | 2 |
| 5.3 | Research paper: writing an overview article: provide a comprehensive foundation on a topic; explain the current state of knowledge; identify gaps in existing studies for potential future research; highlight the main methodologies and research techniques | 2 |

| | | |
|---|---|---|
| 5.4 | Writing Technical Reports: Title page; Summary; Table of contents; Introduction; Body; Figures, tables, equations and formulae; Conclusion; Recommendations. | 1 |
| | | 30 |

## Reference Books


1. SCIENTIFIC WRITING 2.0 A Reader and Writer's Guide: Jean-Luc Lebrun, World ScientiVic Publishing Co. Pte. Ltd., 2011

2. How to Write and Publish a ScientiVic Paper: Barbara Gastel and Robert A. Day, Greenwood publishers, 2016

3. Grammar, Punctuation, and Capitalisation; a handbook for technical writers and editors. www.sti.nasa.gov/publish/sp7084.pdf www.sti.nasa.gov/sp7084/contents.html

4. Everything You Wanted to Know About Making Tables and Figures. http://abacus.bates.edu/%7Eganderso/biology/resources/writing/ HTWtableVigs.html

| 223AGE001 | ADVANCED ENGINEERING MATERIALS | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| | | AUDIT COURSE | 3 | 0 | 0 | - |

**Preamble:** This course is designed in a way to provide a general view on typically used advanced classes of engineering materials including metals, polymers, ceramics, and composites.

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

| | |
|---|---|
| **CO 1** | Analyse the requirement and find appropriate solution for use of materials. |
| **CO 2** | Differentiate the properties of polymers, ceramics and composite materials. |
| **CO 3** | Recognize basic concepts and properties of functional materials. |
| **CO 4** | Comprehend smart and shape memory materials for various applications. |
| **CO 5** | Appraise materials used for high temperature, energy production and storage applications. |

**Mapping of course outcomes with program outcomes**

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

**Assessment Pattern**

| Bloom's Category | End Semester Examination |
|---|---|
| Understand | 60% |
| Apply | 20% |
| Analyse | 20% |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern: 40 marks**

Course based task : 15 marks
Seminar/Quiz : 15 marks
Test paper, 1 no. : 10 marks
Test paper shall include minimum 80% of the syllabus.

**End Semester Examination Pattern:** 60 marks

The examination will be conducted by the respective College. The examination willbe for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any Vive. Each question can carry 12 marks.

**Model Question paper**

AUDIT COURSE

**223AGE001 - ADVANCED ENGINEERING MATERIALS**

**(Answer any five questions. Each question carries 12 Marks)**

| | | |
|---|---|---|
| **1.** | a) State the relationship between material selection and processing. | **5** |
| | b) Write about the criteria for selection of materials with respect to the cost and service requirements for engineering applications. | **7** |
| **2.** | a) Differentiate thermosetting and thermoplastics with suitable examples. | **5** |
| | b) Briefly discuss about the properties and applications of polymer nano composite materials. | **7** |
| **3.** | a) Write about the potential application areas of functionally graded materials. | **5** |
| | b) With a neat sketch describe any one processing technique of functionally graded materials. | **7** |
| **4.** | a) "Smart materials are functional"? Justify the statement. | **5** |
| | b) Explain the terms electrostriction and magnetostriction with its application. | **7** |

| | | |
|---|---|---|
| **5.** | a) What are the factors influencing functional life of components at elevated temperature? | **5** |
| | b) What are super alloys and what are their advantages? | **7** |
| **6** | a) What is a shape memory alloy? What metals exhibit shape memory characteristics? | **4** |
| | b) Explain about the detection capabilities and uses of pyroelectric sensors. | **8** |
| **7** | a) Differentiate between conventional batteries and fuel cells. | **4** |
| | b) Explain the construction and working of a Li-ion battery. | **8** |

**Syllabus**

| Module | Content | Hours | Semester Exam Marks (%) |
|---|---|---|---|
| **I** | Requirements / needs of advanced materials. Classification of materials, Importance of materials selection, Criteria for selection of materials; motivation for selection, cost basis and service requirements. Relationship between materials selection and processing. | **5** | **20** |
| **II** | Classification of non-metallic materials. Polymer, Ceramics: Properties, processing and applications. Nano Composites - Polymer nanocomposites (PNCs), Processing and characterisation techniques – properties and potential applications. | **7** | **20** |
| **III** | Functionally graded materials (FGMs), Potential Applications of FGMs, classification of FGMs, processing techniques. limitations of FGMs. | **6** | **20** |
| **IV** | Smart Materials: Introduction, smart material types - pyroelectric sensors, piezoelectric materials, electrostrictors and magnetostrictors, shape memory alloys – associated energy stimulus and response forms, applications. | **5** | **20** |
| **V** | High Temperature Materials: super alloys – main classes, high temperature properties of superalloys, applications. Energy Materials: materials for batteries. | **7** | **20** |

**Course Plan**

| No | Topic | No. of Lectures |
|---|---|---|
| 1 | **Selection of materials for engineering applications** | |
| 1.1 | Benefits of advanced materials, classification of materials, importance of materials selection | 2 |
| 1.2 | Selection of materials for different properties, strength, toughness, fatigue and creep | 1 |
| 1.3 | Selection for surface durability, corrosion and wear resistance | 1 |
| 1.4 | Relationship between materials selection and processing | 1 |
| **2** | **Classification of non-metallic materials & nano composites** | |
| 2.1 | Rubber: properties, processing and applications. | 1 |
| 2.2 | Plastics: thermosetting and thermoplastics, applications and properties. | 2 |
| 2.3 | Ceramics: properties and applications. | 1 |
| 2.4 | Introduction to nano composites, classification | 1 |
| 2.5 | Processing and characterisation techniques applicable to polymer nanocomposites. | 2 |
| **3** | **Functionally graded materials** | |
| 3.1 | General concept, Potential Applications of FGMs | 2 |
| 3.2 | Classification of FGMs | 1 |
| 3.3 | FGMs processing techniques: powder metallurgy route, melt-processing route | 2 |
| 3.4 | Limitations of FGMs | 1 |
| **4** | **Smart materials** | |
| 4.1 | Introduction to smart materials, types | 1 |
| 4.2 | Pyroelectric sensors-material class, stimulus, detection capabilities and uses | 1 |
| 4.3 | Piezoelectric materials- material class, stimulus, sensing and actuating applications | 1 |
| 4.4 | Electrostrictors and magnetostrictors - material class, stimulus, micro positioning capabilities and applications | 1 |
| 4.5 | Shape memory alloys (SMAs) - material class, stimulus, temperature sensing and high strain responses, applications. | 1 |
| **5** | **High Temperature Materials and Energy Materials** | |
| 5.1 | Characteristics of high-temperature materials, superalloys as high-temperature materials | 1 |
| | superalloys - properties and applications | 2 |
| 5.2 | Introduction to lithium-ion battery (LIBs), operating mechanisms and applications | 2 |
| 5.3 | Introduction to Zn-based battery system, types and existing challenges | 2 |

**Reference Books**


1. DeGarmo et al, “Materials and Processes in Manufacturing”, 10th Edition, Wiley, 2008.
2. R.E. Smallman and A.H.W. Ngan, Physical Metallurgy and Advanced Materials, Seventh Edition, Butterworth-Heinemann, 2007
3. Vijayamohanan K. Pillai and Meera Parthasarathy, “Functional Materials: A chemist’s perspective”, Universities Press Hyderabad (2012).
4. M.V. Gandhi, B.S. Thompson: Smart Materials and Structures, Chapman & Hall, 1992.
5. G. W. Meetham and M. H. Van de Voorde, Materials for High Temperature Engineering Applications (Engineering Materials) Springer; 1 edition (May 19, 2000)
6. Inderjit Chopra, Jayant Sirohi, “Smart Structures Theory”, Cambridge University Press, 2013

| 223AGE003 | DATA SCIENCE FOR ENGINEERS | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| | | AUDIT COURSE | 3 | 0 | 0 | 0 |

**Preamble:** This course covers essentials of statistics and Linear Algebra and how to prepare the data before processing in real time applications. The students will be able to handle missing data and detection of any outliers available in the dataset. This course explores data science, Python libraries and it also covers the introduction to machine learning for engineers.

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

| | |
|---|---|
| **CO 1** | Study Data Science Concepts and statistics |
| **CO 2** | Demonstrate Understanding of Mathematical Foundations needed for Data Science |
| **CO 3** | Understand Exploratory analysis and Data Visualization and Preprocessing on given dataset |
| **CO 4** | Implement Models such as Naive Bayes, K-Nearest Neighbors, Linear and Logistic Regression |
| **CO 5** | Build real time data science applications and test use cases |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | 2 | | 2 | | | 2 | |
| **CO 2** | 2 | | 2 | 1 | | 2 | |
| **CO 3** | 2 | | 2 | 2 | 2 | 2 | |
| **CO 4** | 2 | | 2 | 2 | 3 | 2 | |
| **CO 5** | 2 | | 2 | 3 | 3 | 3 | 2 |

**Assessment Pattern**

| Bloom's Category | End Semester Examination |
|---|---|
| Understand | 50% |
| Apply | 30% |
| Analyse | 20% |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern: 40 marks**

Course based task (Project/Assignments/Simulations/Case studies): 15 marks

Seminar/Quiz : 15 marks

Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

**End Semester Examination Pattern**:**60 marks**

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 mark.

**Syllabus**

| Module | Content | Hours | Semester Exam Marks (%) |
|---|---|---|---|
| I | **Statistics for Data science**<br>Probability: Basic concepts of probability, conditional probability, total probability, independent events, Bayes' theorem, random variable, Population, Sample, Population Mean, Sample Mean, Population Distribution, Sample Distribution and sampling Distribution, Mean, Mode, Median, Range, Measure of Dispersion, Variance, Standard Deviation, Gaussian/Normal Distribution, covariance, correlation. | 6 | 20 |
| II | **Linear Algebra**<br>Vectors and their properties, Sum and difference of Vectors, distance between Vectors, Matrices,Inverse of Matrix, Determinant of Matrix, Trace of a Matrix, Dot Product, Eigen Values, Eigen Vectors, Single Value Decomposition | 6 | 20 |
| III | **Hypothesis Testing**<br>Understanding Hypothesis Testing, Null and Alternate Hypothesis, Non-directional Hypothesis, Directional Hypothesis Critical Value Method, P-Value Method, Types of Errors-Type1 Error,Type2 Error, Types of Hypothesis Test Z Test, Chi-Square | 6 | 20 |

| | | | |
|---|---|---|---|
| **IV** | **Exploratory Data Analysis**<br>Data Collection –Public and Private Data, Data Cleaning-Fixing Rows and Columns, Missing Values, Standardizing values, invalid values, filtering data, Data-Integration,Data-Reduction,Data Transformation | **6** | **20** |
| **V** | **Machine Learning and Python for Data Science**<br>Python Data structures-List, Tuple, Set, Dictionary, Pandas, Numpy, Scipy, Matplotlib, Machine Learning-Supervised Machine Learning, Unsupervised Machine Learning,Regression, Classification, Naïve-Bayes | **6** | **20** |

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY Estd. 2014

**Course Plan**

| **No** | **Topic** | **No. of Lectures** |
|---|---|---|
| 1 | **Statistics for Data science** | |
| 1.1 | Probability: Basic concepts of probability, conditional probability, total probability | 1 |
| 1.2 | independent events, Bayes' theorem, random variable, Population | 1 |
| 1.3 | Sample, Population Mean, Sample Mean, Population Distribution | 1 |
| 1.4 | Sample Distribution and sampling Distribution, Mean, Mode, Median, Range, Propositional logic and predicate logic | 1 |
| 1.5 | Measure of Dispersion, Variance, Standard Deviation | 1 |
| 1.6 | Gaussian/Normal Distribution, covariance, correlation. | 1 |
| **2** | **Linear Algebra** | |
| 2.1 | Vectors and their properties, | 1 |
| 2.2 | Sum and difference of Vectors, distance between Vectors | 1 |
| 2.3 | Matrices,Inverse of Matrix, | 2 |
| 2.4 | Determinant of Matrix, Trace of a Matrix, Dot Product, Eigen Values, Eigen Vectors, Single Value Decomposition | 2 |
| 3 | **Hypothesis Testing** | |
| 3.1 | Understanding Hypothesis Testing, Null and Alternate Hypothesis | 1 |
| 3.2 | Non-directional Hypothesis, Directional Hypothesis Critical Value Method, P-Value Method, | 2 |
| 3.3 | Types of Errors-Type1 Error,Type2 Error, | 1 |
| 3.4 | Types of Hypothesis Test Z Test, Chi-Square, | 2 |
| 4 | **Exploratory Data Analysis** | |
| 4.1 | Data Collection –Public and Private Data | 1 |
| 4.2 | Data Cleaning-Fixing Rows and Columns | 1 |
| 4.3 | Missing Values | 1 |
| 4.4 | Standardizing values | 1 |
| 4.5 | Invalid values, filtering data | 1 |
| 4.6 | Data Integration, Data Reduction, Data Transformation | 1 |

| | | |
|---|---|---|
| 5 | **Machine Learning and Python for Data Science** | |
| 5.1 | Python Data structures-List, Tuple, Set, | 1 |
| 5.2 | Dictionary, Pandas, Numpy, Matplotlib | 2 |
| 5.3 | Machine Learning-Supervised Machine Learning, Unsupervised Machine Learning | 1 |
| 5.4 | Regression, Classification | 1 |
| 5.5 | Naïve-Bayes | 1 |

**Reference Books**


1. Python Data Science Handbook. Essential Tools for Working with Data, Author(s): Jake VanderPlas, Publisher: O'Reilly Media, Year: 2016
2. Practical Statistics for Data Scientists: 50 Essential Concepts, Author(s): Peter Bruce, Andrew Bruce, Publisher: O'Reilly Media, Year: 2017
3. Practical Linear Algebra for Data Science, by Mike X Cohen, Released September 2022, Publisher(s): O'Reilly Media, Inc.
4. Data Science from Scratch ‘by Joel Grus, Released, April 2015, Publisher(s): O'Reilly Media, Inc.
5. Hands-On Exploratory Data Analysis with Python, by Suresh Kumar Mukhiya, Usman Ahmed, Released March 2020,Publisher(s): Packt Publishing

**SET1** **Total Pages:**

Reg No.:__ Name:____________________________

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**

THIRD SEMESTER M.TECH DEGREE EXAMINATION, MARCH 2024

**Course Code: 223AGE003**

**Course Name: DATA SCIENCE FOR ENGINEERS**

Max. Marks: 60 Duration: 2.5 Hours

***Answer any five full questions, each carries 12 marks.***

| | | |
|---|---|---|
| 1 | a ) It is observed that 50% of mails are spam. There is software that filters spam mail before reaching the inbox. It accuracy for detecting a spam mail is 99% and chances of tagging a non-spam mail as spam mail is 5%. If a certain mail is tagged as spam finds the probability that it is not a spam mail. | 5 |
| | b ) Depict the relevance of measures of central tendency in data wrangling with a suitable example | 7 |
| 2. | a) Calculate the inverse of the Matrix $\begin{matrix} 2 & 4 & -6 \\ 7 & 3 & 5 \\ 1 & -2 & 4 \end{matrix}$ | 4 |
| | b)Find all Eigenvalues and Corresponding Eigenvectors for the matrix if $\begin{matrix} 2 & -3 & 0 \\ 2 & -5 & 0 \\ 0 & 0 & 3 \end{matrix}$ | 8 |
| 3. | a) A statistician wants to test the hypothesis H0: $\mu = 120$ using the alternative hypothesis Hα: $\mu > 120$ and assuming that $\alpha = 0.05$. For that, he took the sample values as $n = 40$, $\sigma = 32.17$ and $\bar{x} = 105.37$. Determine the conclusion for this hypothesis? | 5 |
| | b) Hypothesis testing is an integral part of statistical inference, list out the various types of hypothesis testing and also mentions their significances in data science. | 7 |
| 4. | a) Brief in detail directional and non-directional hypothesis | 6 |
| | b) Differentiate null and alternate hypothesis and also elaborate on type 1 and type 2 errors | 6 |
| 5. | a) Explain the concepts of Tuple, List and Directory in python with example | 6 |
| | b) Elucidate reinforcement learning and application in real world. | 6 |

6. a) What is Feature Engineering , demonstrate with an example 6

b) Describe in detail different steps involved in data preprocessing. 6

7. a) Illustrate supervised learning model with linear regression model 5

b) Predict the probability for the given feature vector if an accident will happen or not? 7

Weather condition: rain, Road condition: good, Traffic condition: normal, Engine problem: no, the task is to predict using Naïve Bayes classification.

| SNo. | Weather condition | Road condition | Traffic condition | Engine problem | Accident |
|---|---|---|---|---|---|
| 1 | Rain | bad | high | no | yes |
| 2 | snow | average | normal | yes | yes |
| 3 | clear | bad | light | no | no |
| 4 | clear | good | light | yes | yes |
| 5 | snow | good | normal | no | no |
| 6 | rain | average | light | no | no |
| 7 | rain | good | normal | no | no |
| 8 | snow | bad | high | no | yes |
| 9 | clear | good | high | yes | no |
| 10 | clear | bad | high | yes | yes |

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY KTU Estd. 2014

| 223AGE004 | DESIGN THINKING | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| | | AUDIT COURSE | 3 | 0 | 0 | - |

**Preamble:**

This course offers an introductory exploration of fundamental engineering concepts and techniques, the design process, analytical thinking and creativity, as well as the fundamentals and development of engineering drawings, along with their application in engineering problems.

**Course Outcomes:**

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

| | |
|---|---|
| **CO 1** | Identify and frame design challenges effectively. |
| **CO 2** | Generate creative ideas through brainstorming and ideation |
| **CO 3** | Iterate on designs based on user insights |
| **CO 4** | Apply Design Thinking to real-world problems and projects. |

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

**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:**

**AUDIT COURSES**

**Continuous Internal Evaluation Pattern: 40 marks**

Course based task : 15 marks
Seminar/Quiz : 15 marks
Test paper, 1 no. : 10 marks
Test paper shall include minimum 80% of the syllabus.

**End Semester Examination Pattern:** 60 marks

The examination will be conducted by the respective College. The examination willbe for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 marks.

**Model Question paper**

| | | | |
|---|---|---|---|
| | | **SET1** | **Total Pages:** |
| Reg No.:_______________ | | Name:___________________________ | |
| **APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**<br>THIRD SEMESTER M.TECH DEGREE EXAMINATION, MARCH 2024 | | | |
| **Course Code: 223AGE004** | | | |
| **Course Name: DESIGN THINKING** | | | |
| Max. Marks: 60 | | | Duration: 2.5 Hours |
| ***Answer any five full questions, each carries 12 marks.*** | | | |

| | | |
|---|---|---|
| 1 a) | How can a multidisciplinary team collaborate effectively to implement design principles? | 7 |
| 1 b) | What are the key differences between human-centred design and other design methodologies? | 5 |
| 2 a) | How do you measure the success of a design project in terms of user satisfaction and impact? | 7 |
| 2 b) | How does the iterative nature of the design process contribute to better outcomes | 5 |

| | | |
|---|---|---|
| 3 a) | What are the fundamental principles of effective brainstorming, and how do they differ from traditional problem-solving approaches? | 7 |
| 3 b) | What are some key principles of ergonomic design, and how do they contribute to the usability and comfort of products? | 5 |
| 4 a) | Enumerate some examples of successful and unsuccessful market testing scenarios, and what lessons can be learned from these experiences to improve future product or service launches? | 7 |
| 4b) | What is the primary purpose of creating prototypes in the design and development process? | 5 |
| 5 | What strategies and methodologies can designers use to embrace agility and respond quickly to changing user needs and market dynamics? | 12 |
| 6 | Illustrate any four examples of successful bio-mimicry applications in various industries. | 12 |
| 7 | What ethical considerations should designers keep in mind when designing for diverse user groups? | 12 |
| | **** | |

**Syllabus:**

**Module 1**

Design process: Traditional design, Design Thinking Approach, Introduction to Design Thinking, History and evolution of Design Thinking, Role of design thinking in the human-centred design process. Design space, Design Thinking in a Team Environment, Team formation.

**Module 2**

Design Thinking Stages: Empathize, Define, Ideate, Prototype and Test. The importance of empathy, Building a user-centred mindset. Problem statement formulation, User needs and pain points, establishing target specifications, Setting the final specifications.

**Module 3**

Generating Ideas, Brainstorming techniques, Application of Aesthetics and Ergonomics in Design. Bio-mimicry, Conceptualization, Visual thinking, Drawing/Sketching, Presenting ideas.

**Module 4**

Use of prototyping, Types of prototypes, Rapid prototyping techniques, User testing and feedback collection, Iterative prototyping, testing to gauge risk and market interest

**Module 5**

Entrepreneurship/business ideas, Patents and Intellectual Property, Agility in design, Ethical considerations in design. Overcoming common implementation challenges

**Corse Plan SyllabusandCorsePlan** (For 3credit courses, thec ontent can be for 40 hrs and for2credit courses, the content can be for 26 hrs. The audit course in third semester can have content for 30hours).

| No | Topic | No. of lectures |
|---|---|---|
| **1** | **Design process:** | |
| 1.1 | Design process: Traditional design, Design Thinking Approach, Introduction to Design Thinking, History and evolution of Design Thinking. | 3 |
| 1.2 | Role of design thinking in the human-centred design process. Design space, | 2 |
| 1.3 | Design Thinking in a Team Environment, Team formation. | 2 |

| | | |
|---|---|---|
| **2** | **Design Thinking Stages:** | |
| 2.1 | Design Thinking Stages: Empathize, Define, Ideate, Prototype and Test. | 2 |
| 2.2 | The importance of empathy, Building a user-centred mindset. | 2 |
| 2.3 | Problem statement formulation, User needs and pain points, establishing target specifications, Setting the final specifications. | 3 |
| **3** | **Ideation** | |
| 3.1 | Generating Ideas, Brainstorming techniques. | 2 |
| 3.2 | Application of Aesthetics and Ergonomics in Design. Bio-mimicry. | 3 |
| 3.3 | Conceptualization, Visual thinking, Drawing/Sketching, Presenting ideas. | 2 |
| **4** | **Prototyping and testing** | |
| 4.1 | Use of prototyping, Types of prototypes, Rapid prototyping techniques. | 3 |
| 4.2 | User testing and feedback collection, Iterative prototyping, testing to gauge risk and market interest | 2 |
| **5** | **IPR in design** | |
| 5.1 | Entrepreneurship/business ideas, Patents and Intellectual Property. | 2 |
| 5.2 | Agility in design, Ethical considerations in design. Overcoming common implementation challenges | 2 |

**Reference Books**


1. Christoph Meinel, Larry Leifer and Hasso Plattner- "Design Thinking: Understand – Improve – Apply", Springer Berlin, Heidelberg, 2011.
2. Thomas Lockwood and Edgar Papke – "Design Thinking: Integrating Innovation, Customer Experience, and Brand Value", Allworth Press, 2009.
3. Pavan Soni – "Design Your Thinking", Penguin Random House India Private Limited, 2020.
4. Andrew Pressman- "Design Thinking : A Guide to Creative Problem Solving for Everyone", Taylor & Francis, 2018.
5. N Siva Prasad, "Design Thinking Techniques an Approaches" Ane Books Pvt. Ltd.,2023

**SYLLABUS**

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 223AGE005 | FUNCTIONAL PROGRAMMING IN HASKELL | AUDIT COURSE | 3 | 0 | 0 | - |

**Preamble: This course introduces a functional programming approach in problem solving. Salient features of functional programming like recursion, pattern matching, higher order functions etc. and the implementation in Haskell are discussed.**

**Course Outcomes:**

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

| | |
|---|---|
| **CO 1** | Understand the functional programming paradigm which is based on the mathematics of lambda calculus. |
| **CO 2** | Develop Haskell programs using functions, guards and recursive functions |
| **CO 3** | Apply the concept of tuples, lists and strings in Haskell programming |
| **CO 4** | Apply the concept of algebraic data types, abstract data types, modules, recursive data types and user defined data types in Haskell programming |
| **CO 5** | Develop Haskell programs with files for reading input and storing output |

**Mapping of course outcomes with program outcomes**

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

**Assessment Pattern**

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

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation: 40 marks**

Course based task : 15 marks

Seminar/Quiz : 15 marks

Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

**End Semester Examination: 60 marks**

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 marks.

**Model Question paper**

| | | |
|---|---|---|
| | | **Total Pages:** |
| Reg No.:________________ | | Name:___________________________ |
| **APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**<br>THIRD SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2023 | | |
| **Course Code: 223AGE005** | | |
| **Course Name: Functional Programming in Haskell** | | |
| Max. Marks: 60 | | Duration: 2.5 Hours |
| ***Answer any five full questions, each carries 12 marks.*** | | |

| | | |
|---|---|---|
| 1 a. | Explain the basic differences between imperative style programming and functional style programming. | 3 |
| 1 b. | Analyse each of the following lambda expressions to clarify its structure. If the expression is a function, identify the bound variable and the body expression, and then analyse the body expression. If the expression is an application, identify the function and argument expressions, and then analyse the function and argument expressions:<br>i) λa.(a λb.(b a))<br>ii) λx.λy.λz.((z x) (z y))<br>iii) (λf.λg.(λh.(g h) f) λp.λq.p) | 9 |
| 2 a. | Design a recursive function to find $2^n$ where n is a natural number. | 4 |

| | | |
|---|---|---|
| 2 b. | Explain various forms of function definitions in Haskell with the help of examples. | 8 |
| 3 a. | Explain any three list operations along with function definitions and examples. | 6 |
| 3 b. | Write a program to duplicate only even numbers among the elements of a list using a Haskell function by (i) Recursion (ii) List Comprehension and explain.<br>Example : λ> dupli [1, 2, 3] ANS: [2,2] | 6 |
| 4 | Write Recursive definitions along with an explanation for the below arithmetic operations. Illustrate the recursive flow with the help of a diagram.<br>i. add x y<br>ii. mult x y<br>iii. div x y | 12 |
| 5 | Write the Haskell code to split a list into two lists such that the elements with odd index are in one list while the elements with even index are in the other list. | 12 |
| 6 a | Give the type definition of a binary tree along with explanation of two functions on binary trees. | 6 |
| 6 b | Define a queue data type in Haskell along with any two operations on it with examples. | 6 |
| 7 a. | Explain the basic steps of reading from files and writing to files in Haskell. | 4 |
| 7 b. | Write a Haskell program to read from the file “input.txt”, display the contents on the screen and write the contents to another file “output.txt”. | 8 |
| | **** | |

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

**Module 1 (5 Hrs)**

**Introduction to Functional Programming**: Programming language paradigms, imperative style programming, comparison of programming paradigms.
Functional programming, Functions - Mathematical concepts and terminology, Lambda calculus, Function definitions, programs as functions, Functional programming Languages. Haskell basics, GHCi interpreter.

**Module 2 (6 Hrs)**

**Programming in Haskell:** Expressions and evaluation, Lazy evaluation, let expressions, scopes.

Basic data types in Haskell, operators, infix operators, associativity and precedence, Arithmetic functions.

types, definitions, currying and uncurrying, type abstraction.

Function definitions, pattern matching, guards, anonymous functions, higher order functions.

Recursion, Programming exercises.

**Module 3 (7 Hrs)**

**Data types: tuples and lists**: Tuples , Lists: building lists, decomposing lists, functions on lists, built-in functions on lists, primitive and general recursion over lists, infinite lists.

Strings: functions on strings.

Polymorphism and overloading, conditional polymorphism

**Module 4 (6 Hrs)**

Type classes, Algebraic data types, Modules, Recursive data types.

User defined data types, Records, Stacks, Queues, Binary trees, Constructors, Destructors.

**Module 5 (6 Hrs)**

Functor, Applicative functor, Monad

**Programming with actions:** Functions vs actions, Basics of input / output, the do notation, interacting with the command line and lazy I/O, File I/O.

| No | Topic | No. of Lectures |
|---|---|---|
| 1 | **Introduction to Functional Programming** | |
| 1.1 | Programming language paradigms, imperative style programming, comparison of programming paradigms | 1 |
| 1.2 | Functional programming, Functions - Mathematical concepts and terminology | 1 |
| 1.3 | Lambda calculus | 1 |
| 1.4 | Function definitions, programs as functions, Functional programming Languages | 1 |
| 1.5 | Haskell basics, GHCi interpreter | 1 |
| 2 | **Haskell basics** | |
| 2.1 | Expressions and evaluation, Lazy evaluation | 1 |
| 2.2 | let expressions, scopes, Basic data types in Haskell | 1 |
| 2.3 | operators, infix operators, associativity and precedence, Arithmetic | 1 |

| | | |
|---|---|---|
| | functions | |
| 2.4 | types, definitions, currying and uncurrying, type abstraction. | 1 |
| 2.5 | Function definitions, pattern matching, Guards | 1 |
| 2.6 | anonymous functions, higher order functions, Recursion | 1 |
| 3 | **Data types: tuples and lists** | |
| 3.1 | Tuples , Lists: building lists, decomposing lists | 1 |
| 3.2 | functions on lists, built-in functions on lists | 1 |
| 3.3 | primitive and general recursion over lists | 1 |
| 3.4 | infinite lists | 1 |
| 3.5 | Strings: functions on strings | 1 |
| 3.6 | Polymorphism and overloading | 1 |
| 3.7 | conditional polymorphism | 1 |
| 4 | **User defined data types** | |
| 4.1 | Type classes, Algebraic data types, Modules | 1 |
| 4.2 | Recursive data types | 1 |
| 4.3 | User defined data types, Records | 1 |
| 4.4 | Stacks, Queues | 1 |
| 4.5 | Binary trees | 1 |
| 4.6 | Constructors, Destructors | 1 |
| 5 | **Programming with actions** | |
| 5.1 | Functor, Applicative functor, | 1 |
| 5.2 | Monad | 1 |
| 5.3 | Programming with actions: Functions vs actions, Basics of input / output, the do notation | 1 |
| 5.4 | interacting with the command line and lazy I/O | 1 |
| 5.5 | File I/O | 2 |

**Reference Books**

[1] Richard Bird, “Introduction to functional programming using Haskell', second edition, Prentice hall series in computer science

[2] Bryan O'Sullivan, Don Stewart, and John Goerzen, “Real World Haskell”

[3] Richard Bird, "Thinking Functionally with Haskell", Cambridge University Press, 2014

[4] Simon Thompson, "Haskell: The Craft of Functional Programming", Addison-Wesley, 3rd Edition, 2011

[5] H. Conrad Cunningham, "Notes on Functional Programming with Haskell", 2014

[6] Graham Hutton, "Programming in Haskell", Cambridge University Press, 2nd Edition, 2016

[7] Alejandro Serrano Mena, "Practical Haskell: A Real-World Guide to Functional Programming", 3rd Edition, Apress, 2022

[8] Miran Lipovaca, "Learn You a Haskell for Great Good!: A Beginner's Guide", No Starch Press, 2011

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY KTU Estd. 2014

| 223AGE010 | REUSE AND RECYCLE TECHNOLOGY | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| | | AUDIT COURSE | 3 | 0 | 0 | - |

**Preamble:** "Reuse and Recycle Technology" typically focuses on sustainable practices and technologies aimed at reducing waste, conserving resources, and promoting environmental responsibility.

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

| | |
|---|---|
| **CO 1** | Explain the principles and technologies behind waste reduction, resource conservation, and sustainable practices |
| **CO 2** | Describe and Analyze waste generation and management. |
| **CO 3** | Apply the knowledge of various reuse strategies and their application in different industries and Analyze various recycling technologies |
| **CO 4** | Appraise the methods of E-waste management and Eco friendly packaging |
| **CO 5** | Comprehend Environmental Regulations and Policies, Understand the importance of environmental regulations and policies in addressing environmental challenges |

**Mapping of course outcomes with program outcomes**

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

**Assessment Pattern**

| Bloom's Category | End Semester Examination |
|---|---|
| Understand | 60% |
| Apply | 20% |
| Analyse | 20% |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern: 40 marks**

Course based task : 15 marks
Seminar/Quiz : 15 marks
Test paper, 1 no. : 10 marks
Test paper shall include minimum 80% of the syllabus.

**End Semester Examination Pattern:** 60 marks

The examination will be conducted by the respective College. The examination willbe for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 marks.

**Model Question paper**

AUDIT COURSE

**223AGE010 - REUSE AND RECYCLE TECHNOLOGY**

***Answer any five full questions, each carries 12 marks.***

| | | |
|---|---|---|
| **1.** | (a) What are the 3 pillars of sustainability?<br>*(b)* What is sustainable waste management? What makes sustainable waste management so important? | 5<br>7 |
| **2.** | (a)How do the three categories of municipal solid waste differ?<br>*(b)* Discuss the municipal waste collection and management? | 5<br>7 |
| **3.** | (a)Explain the major differences between Reuse and Recycle?<br>*(b)* Give an overview of recycling technologies used for any two materials. Discuss the Process involved. | 5<br>7 |
| **4.** | (a)What are the common source of E-waste<br>*(b)* What are the challenges and opportunities in E-waste management | 5<br>7 |
| **5.** | (a)What is the case law for waste recycling in India<br>*(b)* Discuss sustainable packaging and its environmental impacts | 5<br>7 |
| **6.** | Explain the various environmental regulations in India for addressing Environmental challenges | 12 |
| **7.** | a) Give examples of water reuse technologies in circular economy<br>b) How can we reduce e-waste with sustainable solutions | 5<br>7 |

## Syllabus

| Module | Content | Hours | Semester Exam Marks (%) |
|---|---|---|---|
| **I** | **Introduction to Sustainability**, Understanding sustainability and its importance, The three pillars of sustainability: Environmental, Social, and Economic. Biodiversity conservation, Climate change and mitigation Sustainable resource management. | **6** | **20** |
| **II** | **Waste Management,** Definition and classification of waste, Waste Generation and Composition**,** Waste Collection and Transportation, Waste Segregation and Sorting. Waste Disposal Methods Historical perspectives on waste management, The three Rs: Reduce, Reuse, and Recycle. | **6** | **20** |
| **III** | **Recycling and Reuse:** Importance of reuse, Application of reuse in various industries, Challenges and opportunities in reuse, Overview of recycling technologies, Circular economy, Sorting and processing of recyclable materials, Advanced recycling methods. Emerging technologies in recycling. | **6** | **20** |
| **IV** | **E-waste Recycling,** Challenges and environmental impact of electronic waste, E-waste recycling methods and regulations, Sustainable electronics design, **Sustainable Packaging,** Packaging materials and their environmental impact, Eco-friendly packaging alternatives, Packaging design for sustainability | **6** | **20** |
| **V** | **Environmental Regulations and Policies,** Understand the importance of environmental regulations and policies in addressing environmental challenges, National and international waste and recycling regulations, Compliance and enforcement, Industry standards and certifications | **6** | **20** |

## Course Plan

| No | Topic | No. of Lectures |
|---|---|---|
| 1 | **Introduction to Sustainability (6)** | |
| 1.1 | Understanding sustainability and its importance | 1 |
| 1.2 | The three pillars of sustainability: Environmental, Social, and Economic. | 3 |
| 1.3 | Biodiversity conservation, Climate change and mitigation | 1 |
| 1.4 | Sustainable resource management | 1 |
| **2** | **Waste Management (6)** | |
| 2.1 | Definition and classification of waste | 1 |
| 2.2 | Waste Generation and Composition | 1 |
| 2.3 | Waste Collection and Transportation. | 1 |
| 2.4 | Waste Segregation and Sorting. | 1 |
| 2.5 | Waste Disposal Methods | 1 |
| 2.6 | Historical perspectives on waste management, The three Rs: Reduce, Reuse, and Recycle. | 1 |
| **3** | **Recycling and Reuse (6)** | |
| 3.1 | Importance of reuse, Examples of reuse in various industries. | 1 |
| 3.2 | Challenges and opportunities in reuse | 1 |
| 3.3 | Overview of recycling technologies, Sorting and processing of recyclable materials | 2 |
| 3.4 | Advanced recycling methods | 1 |
| 3.5 | Emerging technologies in recycling. | 1 |
| **4** | **E-waste Recycling (6)** | |
| 4.1 | Challenges and environmental impact of electronic waste | 1 |
| 4.2 | E-waste recycling methods and regulations | 1 |
| 4.3 | Sustainable electronics design | 1 |
| 4.4 | Packaging materials and their environmental impact | 1 |
| 4.5 | Eco-friendly packaging alternatives | 1 |
| 4.6 | Packaging design for sustainability | 1 |
| **5** | **Environmental Regulations and Policies (6)** | |
| 5.1 | Importance of environmental regulations and policies in addressing environmental challenges | 2 |
| 5.2 | National and international waste and recycling regulations | 2 |
| 5.3 | Industry standards and certifications, Compliance and enforcement | 2 |

**Reference Books**


1. Sustainable Engineering: Concepts, Design and Case Studies, David T. Allen, Pearson Publication.
2. A Comprehensive Book on Solid Waste Management with Application, Dr. H.S. Bhatia , Misha Books, 2019
3. "Cradle to Cradle: Remaking the Way We Make Things" by William McDonough and Michael Braungart.
4. "Recycling of Plastic Materials" edited by Vijay Kumar Thakur
5. E-waste: Implications, Regulations and Management in India and Current Global Best Practices, Rakesh Johri, TERI
6. "Sustainable Packaging", Subramanian Senthilkannan Muthu , Springer Nature.
7. **I**ndian Environmental Law: Key Concepts and Principles " Orient Black swan Private Limited, New Delhi.

| 223AGE012 | EXPERT SYSTEMS | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| | | AUDIT COURSE | 3 | 0 | 0 | - |

**Preamble:** The course aims to provide an understanding of the basic concepts of Artificial Intelligence (AI) and Expert Systems. The course also covers the knowledge representation in expert systems, classes of expert systems, applications of expert systems.

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

| | |
|---|---|
| **CO 1** | Explain the concepts of Artificial Intelligence and different ways of knowledge representations. |
| **CO 2** | Explain the components of expert systems, development stages of expert systems and tools available for expert system design. |
| **CO 3** | Apply the concept of knowledge representation in expert systems |
| **CO 4** | Differentiate the classes of expert systems and examine properties of existing systems |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | 1 | | 2 | 1 | 2 | 2 | |
| **CO 2** | 1 | | 1 | 3 | 2 | 2 | |
| **CO 3** | 1 | | 1 | 2 | 2 | 2 | |
| **CO 4** | 2 | | 2 | 2 | 3 | 2 | |

**Assessment Pattern**

| Bloom's Category | End Semester Examination |
|---|---|
| Understand | 60% |
| Apply | 20% |
| Analyse | 20% |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern: 40 marks**

Course based task (Project/Assignments/Simulations/Case studies): 15 marks

Seminar/Quiz : 15 marks

Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

**End Semester Examination Pattern**:**60 marks**

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 mark.

| | | |
|---|---|---|
| **APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**<br>THIRD SEMESTER M.TECH DEGREE EXAMINATION, MARCH 2024 | | |
| **Course Code: 223AGE012** | | |
| **Course Name: EXPERT SYSTEMS** | | |
| Max. Marks: 60 | | Duration: 2.5 Hours |
| ***Answer any five full questions, each carries 12 marks.*** | | |

| | | |
|---|---|---|
| 1 | a) What are the types of AI? Explain with examples . | 6 |
| | b) What do you mean by knowledge in AI and explain the different ways of knowledge representation used in AI? | 6 |
| 2. | a) Write note on semantic network. | 6 |
| | b) What are Predicates? Explain its syntax and semantics. | 6 |
| 3. | a) Write notes on different tools available for expert system design. | 6 |
| | b). What are the different stages in the development of an expert system? | 6 |
| 4. | a) Illustrate Conceptual Dependencies with an example. | 6 |
| | b) Illustrate with an example the Structured Knowledge representation of an Expert System. | 6 |
| 5. | a) What do you mean by Frame based Expert System? Explain | 6 |
| | b)Explain the architecture of MYCIN | 6 |
| 6. | a)Explain Fuzzy based expert systems | 6 |
| | b) Explain the neural network based expert systems | 6 |
| 7. | a) Explain any two applications of expert systems? | 6 |
| | b)What are the limitations of expert system ? Explain | 6 |

**Syllabus**

| Module | Content | Hours | Semester Exam Marks (%) |
|---|---|---|---|
| **I** | Overview of Artificial Intelligence (AI): Definition & Importance of AI.<br><br>Knowledge general concepts: Definition and Importance of knowledge, Knowledge-Based Systems, Knowledge organization, Knowledge Manipulation and acquisition.<br><br>Knowledge Representation: Introduction, Syntax and Semantics- Propositional logic and predicate logic. | **6** | **20** |
| **II** | Basic concepts of expert systems-Introduction to expert systems, Components of expert systems. Features of Expert System, Stages in the development of expert system, Types of tools available for expert system design | **6** | **20** |
| **III** | Knowledge representation in expert systems: Structured Knowledge representation: Graphs, Frames and related structures, Associative networks, Conceptual dependencies, Examples of structured knowledge representation. | **6** | **20** |
| **IV** | Classes of expert systems: Rule-based expert systems, Example- MYCIN, Frame-based expert system, terminologies, IF-THEN structure. Fuzzy and Neural network based expert systems(basic concepts) | **7** | **20** |
| **V** | Currents trends in expert systems, Advantages and limitations of expert systems, Applications of expert systems. | **5** | **20** |

**Course Plan**

| No | Topics | No. of Lectures |
|---|---|---|
| 1 | **Overview of Artificial Intelligence& Knowledge general concepts** | |
| 1.1 | Definition & Importance of AI | 1 |
| 1.2 | Definition and Importance of Knowledge, | 1 |
| 1.3 | Knowledge-Based Systems, Knowledge Organization | 1 |
| 1.4 | Knowledge Manipulation and acquisition | 1 |
| 1.5 | Knowledge Representation: Introduction, Syntax and Semantics | 1 |
| 1.6 | Propositional logic and predicate logic | 1 |
| 2 | **Basic concepts of expert systems** | |
| 2.1 | Introduction to Expert System, Components of expert systems | 2 |
| 2.2 | Features of Expert System, Stages in the development of expert system | 2 |
| 2.3 | Types of tools available for expert system design | 2 |
| 3 | **Knowledge representation in expert systems** | |
| 3.1 | Structured Knowledge representation | 1 |
| 3.2 | Graphs, Frames and Related Structures | 2 |
| 3.3 | Associative Networks, Conceptual Dependencies | 2 |
| 3.4 | Examples of structured knowledge representation | 1 |
| 4 | **Classes of expert systems** | |
| 4.1 | A rule-based expert system -Introduction | 1 |
| 4.2 | MYCIN | 1 |
| 4.3 | IF-THEN structure | 1 |
| 4.4 | Frame-based expert system | 2 |
| 4.5 | Fuzzy based expert systems | 1 |
| 4.6 | Neural network based expert systems | 1 |
| 5 | **Currents trends and applications of expert systems** | |
| 5.1 | Currents trends of expert systems | 2 |
| 5.2 | Advantages and limitations of expert systems | 1 |
| 5.3 | Applications of expert systems | 2 |

**Reference Books**


1. E. Rich & K. Knight - Artificial Intelligence, 2/e, TMH, New Delhi, 2005.
2. P.H. Winston - Artificial Intelligence, 3/e, Pearson Edition, New Delhi, 2006.
3. D.W. Rolston - Principles of AI & Expert System Development, TMH, New Delhi
4. Kevin Night and Elaine Rich, Nair B., “Artificial Intelligence (SIE) “, McGraw Hill – 2010
5. Dan W Patterson, ‘Introduction to Artificial intelligence and Expert systems’, Prentice Hall of India Pvt. Ltd,2007
6. Russel (Stuart), ‘Artificial Intelligence- Modern approach, Pearson Education series in AI’, 3rd Edition, 2009.
7. I. Gupta, G. Nagpal · Artificial Intelligence and Expert Systems, Mercury Learning and Information -2020

| 223AGE011 | SYSTEM MODELLING | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| | | AUDIT COURSE | 3 | 0 | 0 | - |

**Preamble:** Study of this course provides the learners a clear understanding of fundamental concepts in simulation and modelling. This course covers the different statistical models, importance of data collection and various types of simulations. The course helps the learners to find varied applications in engineering, medicine and bio-technology.

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

| | |
|---|---|
| **CO 1** | Analyse the requirement and find appropriate tool for simulation. |
| **CO 2** | Differentiate the different statistical models. |
| **CO 3** | Discuss the different techniques for generating random numbers. |
| **CO 4** | Analyse the different methods for selecting the different input models.. |
| **CO 5** | Discuss the different measures of performance and their estimation |

**Mapping of course outcomes with program outcomes**

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

**Assessment Pattern**

| Bloom's Category | End Semester Examination |
|---|---|
| Understand | 60% |
| Apply | 20% |
| Analyse | 20% |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern:**

Course based task (Project/Assignments/Simulations/Case studies): 15 marks
Seminar/Quiz: 15 marks
Test paper, 1 no.: 10 marks
Test paper shall include minimum 80% of the syllabus.

**End Semester Examination Pattern:**

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 marks.

**Model Question paper**

AUDIT COURSE

**223AGE001 – SYSTEM MODELLING**

***Answer any five questions Each carries 12 marks***

**PART A**

1. a. Discuss the advantages and disadvantages of simulation. (5marks)

   b. What are the areas of applications of simulation (7 marks)

2. a.A bus arrives every 20 minutes at a specified stop beginning at 6:40 A.M. and continuing until 8:40 A.M. A certain passenger does not know the schedule, but arrives randomly (uniformly distributed) between 7:00A.M. and 7:30 A.M. every morning. What is the probability that the passenger waits more than 5 minutes for a bus? (5 marks)

   b. A production process manufactures computer chips on the average at 2% nonconforming. Every day, a random sample of size 50 is taken from the process. If the sample contains more than two nonconforming chips, the process will be stopped. Compute the probability that the process is stopped by the sampling scheme. (7 marks)

3. a.Discuss the different types of tests for random numbers. (5 marks)

   b. Generate random numbers using multiplicative congruential method with X0 = 5, a 11, and m = 64. (7 marks)

4. a. What are the different methods of data collection. (4marks)

   b. Records pertaining to the monthly number of job-related injuries at an underground coalrnine were being studied by a federal agency. The values for the past 100 months were as follows:

| Injuries per Month | Frequency of Occurrence |
|---|---|
| 0 | 35 |
| 1 | 40 |
| 2 | 13 |
| 3 | 6 |
| 4 | 4 |
| 5 | 1 |
| 6 | 1 |

(a) Apply the chi-square test to these data to test the hypothesis that the underlying distribution is Poisson. Use the level of significance α== 0.05.
(b) Apply the chi-square test to these data to test the hypothesis that the distribution is Poisson with mean 1.0. Again let α = 0.05. ·
c) What are the differences between parts (a) and (b), and when might each case arise? (8 marks)

5. a.What is the difference between validation and verification.(5 marks)
b. Discuss the different measures of performance and their estimation(7 marks)
6. a. Discuss the different methods of parameter estimation(5 marks)
b. With an example, describe the Poisson process.(7 marks)
7. a. Distinguish between discrete and continuous systems(5 marks)
b.What are the different components of a simulation system(7 marks)

**Syllabus**

| Module | Content | Hours | Semester Exam Marks (%) |
|---|---|---|---|
| I | When simulation is the appropriate tool. Advantages and disadvantages of Simulation; Areas of application, Systems and system environment; Components of a system; Discrete and continuous systems, Model of a system; Types of Models, Discrete-Event System Simulation, Steps of a simulation study. | 6 | 20 |
| II | Review of terminology and concepts, Useful statistical models, Discrete distributions. Continuous distributions, Poisson process, Empirical distributions. (basic idea only) | 6 | 20 |
| III | Properties of random numbers; Generation of pseudo-random numbers, Techniques for generating random numbers, Tests for Random Numbers | 6 | 20 |
| IV | Data Collection; Identifying the distribution with data, Parameter estimation, Goodness of Fit Tests, Fitting a non-stationary Poisson process, Selecting input models without data, Multivariate and Time-Series input models. | 6 | 20 |
| V | Measures of performance and their estimation, Output analysis for terminating simulations, Output analysis for steady-state simulations, Verification, calibration and validation | 6 | 20 |

## Course Plan

| No | Topic | No. of Lectures |
|---|---|---|
| 1 | **Introduction** | |
| 1.1 | When simulation is the appropriate tool | 1 |
| 1.2 | Advantages and disadvantages of Simulation; | 1 |
| 1.3 | Areas of application, Systems and system environment; | 1 |
| 1.4 | Components of a system; Discrete and continuous systems, | 1 |
| 1.5 | Model of a system; Types of Models, | 1 |
| 1.6 | Discrete-Event System Simulation ,Steps of a simulation study | 1 |
| **2** | **Statistical Models in Simulation** | |
| 2.1 | Review of terminology and concepts, Empirical distributions. (basic idea only) | 1 |
| 2.2 | Useful statistical models, | 1 |
| 2.3 | Discrete distributions. | 1 |
| 2.4 | Continuous distributions,. | 1 |
| 2.5 | Poisson process | 1 |
| 2.6 | Empirical distributions | 1 |
| **3** | **Random Number Generation** | |
| 3.1 | Properties of random numbers; | 1 |
| 3.2 | Generation of pseudo-random numbers, | |
| 3.3 | Techniques for generating random numbers | 1 |
| 3.4 | Techniques for generating random numbers(cont) | 1 |
| 3.5 | Tests for Random Numbers | 1 |
| 3.6 | Tests for Random Numbers(cont) | 1 |
| **4** | **Input Modelling** | |
| 4.1 | Data Collection; | 1 |
| 4.2 | Identifying the distribution with data. | 1 |
| 4.3 | Parameter estimation, Goodness of Fit Tests | 1 |
| 4.4 | Fitting a non-stationary Poisson process | 1 |
| 4.5 | Selecting input models without data, | 1 |
| 4.6 | Multivariate and Time-Series input models | 1 |
| **5** | **Measures of Performance and their Estimation** | |
| 5.1 | Measures of performance and their estimation | 1 |
| 5.2 | Measures of performance and their estimation(cont) | 1 |
| 5.3 | Output analysis for terminating simulations | 1 |
| 5.4 | Output analysis for steady-state simulations | 1 |
| 5.5 | Verification, calibration and validation | 1 |
| 5.6 | Verification, calibration and validation(cont) | 1 |

**Textbooks:**

1. Jerry Banks, John S. Carson II, Barry L. Nelson, David M. Nicol: Discrete-Event System Simulation, 5th Edition, Pearson Education, 2010.

**Reference Books:**

1. Lawrence M. Leemis, Stephen K. Park: Discrete – Event Simulation: A First Course, Pearson Education, 2006.

2. Averill M. Law: Simulation Modeling and Analysis, 4 th Edition, Tata McGraw-Hill, 2007

3. System Modelling and Response by Ernest O. Doebelin

4. Averill M Law, "Simulation Modeling and Analysis",McGraw-Hill Inc,2007 Geoffrey Gorden, "System Simulation",Prentice Hall of India,1992.

| 223AGE009 | Principles of Automation | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| | | CREDIT COURSE | 3 | 0 | 0 | 0 |

**Preamble:**

This course deals in detail with the various aspects of automation such as sensors, actuators, controllers, mechanical and electrical elements and their integration for automating new and existing manufacturing and process industries and applications. This course will be beneficial to students in designing automation schemes for industries and to design automated systems

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

| | |
|---|---|
| **CO 1** | Explain the fundamentals of sensor systems and to choose a suitable sensor system for the given application based on the evaluation of the constraints. |
| **CO 2** | Explain the fundamentals of signal conditions and to design a suitable signal conditioning scheme for given application. |
| **CO 3** | Describe the characteristics of various actuator systems and to decide the right type of actuator for the given application. |
| **CO 4** | Describe the importance of an industrial robot and fundamentals of numerical control in automation. |
| **CO 5** | Explain the fundamentals of controllers used in industrial automation and to construct simple automation schemes by ladder logic programs. |

**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 | | |
| **CO 2** | 2 | | 2 | 2 | 2 | | |
| **CO 3** | 2 | | 2 | 2 | 2 | | |
| **CO 4** | 2 | | 2 | 2 | 2 | | |
| **CO 5** | 2 | | 2 | | | | |

**Assessment Pattern**

| Bloom's Category | End Semester Examination |
|---|---|
| Understand | 70 % |
| Apply | 30 % |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern: 40 marks**

Course based task (Project/Assignments/Simulations/Case studies): 15 marks
Seminar/Quiz: 15 marks
Test paper, 1 no.: 10 marks
Test paper shall include minimum 80% of the syllabus.

**End Semester Examination Pattern**:**60 marks**

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 marks.

Model Question Paper

**223AGE009 Principles of Automation**

Time 2.5 Hrs                                                                 Marks 60

***Answer any five questions Each carries 12 marks***

1. (a) Differentiate the static and dynamic characteristics of a temperature sensor and explain how it affects the selection of a suitable temperature sensor. (6 marks)
   (b) Explain the working of a strain-gauge. (6marks)

2. (a) Explain why anti-aliasing filters are used in analog to digital converters. (3 marks)
   (b) Design a first order low pass filter with a cutoff frequency of 2 kHz. (9 marks)

3. (a) What are the factors to consider while deciding choosing between hydraulic, pneumatic or electrical actuation systems for an automation scheme? (4 marks)
   (b) Explain the working of a three-way pressure reducing valve. (4 marks)
   (c) Explain the working of solenoids. In what applications would you use a Solenoid valve. (4 marks)

4. (a) Explain the principle of the Touch sensor and also mention how they are used in robots. (5 marks)
   (b) Explain the basic terminologies in robotic system and also explain the components of robotic system. (7 marks)

5. (a)With neat schematic explain the architecture of the PLC. (6 marks)
   (b) Explain the use of an up-down counter in PLC with a suitable example. (6 marks)

6. (a) Write short note on SCADA. What is difference PLC and SCADA? (3 marks)

   (b)Construct a ladder logic for controlling a process tank as per the logic given below;
      i.The tank should be filled by a valve V1 when low level float switch L1 is ON and an external input S1 is received.

ii. V1 should be closed when the liquid level reaches a high-level float switch L2.
iii. An agitator motor should be turned on after a delay of 5sec after L2 is triggered.
iv. After agitating for 30mins, contents of the tank should be emptied by opening another valve V2.
v. The temperature should be maintained at 70℃ using a thermostat T1 and Heater H (9 marks)

7. (a) Explain the levels of Automation. (6 marks)
(b) Explain the working of Flow sensor (6 marks)

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

**Syllabus and Course Plan**

| No | Topics | No. of Lectures |
|---|---|---|
| 1 | **Introduction to Industrial Automation** | |
| 1.1 | Basic Elements of an Automated System, Levels of Automation | 2 |
| 1.2 | Hardware components for Automation: Sensors, classification, Static and dynamic behaviour of sensors. | 2 |
| 1.3 | Basic working principle of different sensors: Proximity sensors, Temperature sensors, flow sensors, Pressure sensors, Force sensors. Position sensors | 4 |
| 2 | **Signal conditioning** | |
| 2.1 | Need for signal conditioning, Types of signal conditioning. | 2 |
| 2.2 | Signal conditioning using operational amplifier-Amplifier (Inverting and Non-inverting) and Filter circuits (Basic concepts). Design of first order low pass filter. | 2 |
| 2.3 | Signal conditioning for data acquisition systems, anti-aliasing filters, Analog–Digital Conversions, Analog-to-Digital Converters (ADC)-Steps in analog-to-digital conversion, Successive Approximation Method, Digital-to-Analog Converters (DAC)- Steps in digital to analog conversion, Zero-order and first order data hold circuits | 4 |
| 3 | **Actuators** | |
| 3.1 | Types of actuators- mechanical, electrical, pneumatic and hydraulic actuators. (Basic working principle) | 2 |
| 3.2 | Mechanical systems for motion conversion, transmission systems | 3 |
| 3.3 | Solenoids, Electric and stepper motors control. | 3 |
| 4 | **Robotics and Automated Manufacturing Systems** | |
| 4.1 | Robot Anatomy and Related Attributes: Joints and Links, Common Robot Configurations, Joint Drive Systems, Sensors in Robotics (Basic concepts) | 3 |
| 4.2 | Robot Control Systems, Applications of Industrial Robots- Material handling | 4 |
| 4.3 | Fundamentals of Numerical control (NC) Technology | 1 |
| 5 | **Discrete Control and Programmable Logic Controllers** | |

| | | |
|---|---|---|
| 5.1 | Discrete Process Control: Logic and Sequence control | 2 |
| 5.2 | Ladder Logic Diagrams, Programmable Logic Controllers: Components of the PLC, PLC Operating Cycle, Programming the PLC (Basic concepts only) | 4 |
| 5.3 | Introduction to Distributed control system (DCS) and Supervisory Control and Data Acquisition Systems (SCADA) | 2 |

**Reference Books**


1. Mikell Groover, Automation, Production Systems, and Computer-Integrated Manufacturing, 5th Edition, Pearson, 2019.
2. Yoram Koren, “Computer Control of Manufacturing Systems”,TataMcGraw Hill Edition2005.
3. S. R. Deb; Sankha Deb. Robotics Technology and Flexible Automation, Second Edition McGraw-Hill Education: New York, 2010.
4. W. Bolton, “Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering” - PrenticeHall- 2013 - 5th Edition.
5. Doebelin, E.O. and Manic, D.N., “Measurement Systems: Applications and Design”, 7th Edition, McGraw Hill, 2019.
6. Krishna Kant, Computer Based Industrial Control-, EEE-PHI,2nd edition,2010.
7. Nathan Ida, Sensors, Actuators, and Their Interfaces- A multidisciplinary introduction, 2nd Edition, IET Digital Library, 2020.
8. Salivahanan, S., and VS Kanchana Bhaaskaran. Linear integrated circuits. McGraw-Hill Education, 2nd edition, 2014.
9. Petruzella, Frank D. Programmable logic controllers. Tata McGraw-Hill Education, 2005
10. Chapman and Hall, “Standard Handbook of Industrial Automation”, Onsidine DM C & Onsidine GDC”, NJ, 1986

| 223AGE002 | FORENSIC ENGINEERING | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| | | Audit Course | 3 | 0 | 0 | - |

**Preamble:** This course explores various aspects of Forensic Engineering and different methods ,tools and procedures used by Engineers to investigate and analyze . The students will learn to develop their awareness in Forensic Engineering .

**Pre-requisite:** Nil

**Course Outcomes:**

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

| | |
|---|---|
| **CO 1** | Identify the fundamental aspects of forensic Engineering |
| **CO 2** | Apply forensic Engineering in Practical work flow and Investigation |
| **CO 3** | Apply methods and analysis in Forensic Investigation |
| **CO 4** | Develop practical strategies and standards of Investigation |
| **CO 5** | Create an awareness in criminal cases and create Engineering expertise in court room on forensic Engineering |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | 2 | 2 | 3 | 3 | 3 | 3 | |
| **CO 2** | 2 | 2 | 3 | 3 | 3 | 3 | 1 |
| **CO 3** | 3 | 3 | 3 | 3 | 3 | 3 | 1 |
| **CO 4** | 3 | 3 | 3 | 3 | 3 | 3 | 1 |
| **CO 5** | 3 | 3 | 3 | 3 | 3 | 3 | |

**Assessment Pattern**

| Bloom's Category | Continuous Internal Evaluation | End Semester Examination |
|---|---|---|
| Apply | 40 % | 60 % |
| Analyse | 40 % | 40 % |
| Evaluate | 20 % | |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation: 40 marks**

Course based task :15marks

Seminar/Quizz :15marks

Test paper :10 marks

Test paper shall include minimum 80% of the syllabus.

**End Semester Examination: 60 marks**

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 marks.

**Model Question paper**

## APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

**THIRD SEMESTER M. TECH DEGREE EXAMINATION**

**Course Code: 223AG002**

**Course Name: FORENSIC ENGINEERING**

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

**PART A**

***Answer any 5 questions, each question carries 12 marks.*** **Marks**

| | | | |
|---|---|---|---|
| 1. | (a) | What are the uses of forensic engineering in legal laws ? | (7) |
| | (b) | Discuss the professional responsibility of a forensic Engineer . | (5) |
| 2. | (a) | What are the steps in preliminary on site Investigation ? | (7) |
| | (b) | With suitable examples, explain photo cataloguing? | (5) |
| 3. | (a) | Discuss STEP method . | (7) |
| | (b) | Explain root cause Analysis | (5) |
| 4. | (a) | Detail about EDAX Method. | (7) |
| | (b) | Enlist the uses of NDT in forensic Analysis with example | (5) |
| 5. | (a) | Differentiate NFPA & FMV Standards | (7) |
| | (b) | Briefly discuss the term Email Phishing ? | (5) |
| 6. | | Define the responsibility and duty of a forensic expert in the court. | (12) |
| 7. | | Explain Forensic Engineering workflow with examples | (12) |

## Syllabus and Course Plan

| Module No | Topic | No. of Lectures (Hours) |
|---|---|---|
| **1** | **Module 01: Introduction to Forensic Engineering (6 Hours)** | |
| 1.1 | Forensic Engineering-Definition, Investigation Pyramid, Eyewitness Information, Role in Legal System | 2 |
| 1.2 | Scientific Method-Applying scientific methods in Forensic Engineering-Engineer as expert Witness-Scientific methods and legal system | 2 |
| 1.3 | Qualification of Forensic Engineer-Technical- Knowledge- Oral-written-Communication- other skills-Personality Characteristics | 1 |
| 1.4 | Ethics and professional responsibilities. | 1 |
| **2** | **Module 02: Forensic Engineering Workflow and Investigation Methods (6 Hours)** | |
| 2.1 | Forensic Engineering Workflow-Team &planning-preliminary onsite investigation. Sampling-selection of sample-collection- packing-sealing of samples. | 2 |
| 2.2 | Source and type of evidence - Paper documentation- digital documentation-electronic data. Physical Evidence-Collection of photograph-cataloguing -Recognizing the Evidence-organizing-Evidence Analysis -Reporting | 2 |
| 2.3 | Investigation Methods- Cause and Causal mechanism analysis-Time and event sequence-STEP method. Human Factors, Human errors - Analysis of Operative Instruction and working Procedures | 2 |
| **3** | **Module 03: Physical Product Failure & Analytical Methods (6 Hours)** | |
| 3.1 | Introduction to typical Forensic Engineering Tool box-NDT, Crack detection and human eye -Hardness testing- and Destructive testing Methods with case studies | 2 |
| 3.2 | Indirect stress strain Analysis-Brittle lacquer technique, Contact Radiography-Metallography-EDAX method | 1 |
| 3.3 | Forensic Optical Microscopy-Examination- Magnification-USB Microscopy -Wifi Enabled microscopy -Reflected microscopy | 2 |
| 3.4 | Novel Tools and System -Contour Method-Flash Thermography-Thermographic signal reconstruction (TSR)-Electromagnetically induced acoustic Emission (EMAE)-Pulsed Eddy Current (PEA)-Theory only | 1 |
| **4** | **Module 04: Cyber Forensic , Civil ,Electrical Accidents & Standards (6 Hours)** | |
| 4.1 | Basics of Digital & Cyber forensics: Technical concepts; labs and tools; collecting evidence Operating System Forensic basics with - Windows, Linux -Mobile Forensic-Anti forensics-Malware- Web attack forensics with Email Crimes-Cyber Laws | 3 |
| 4.2 | Different types of Forensic accident investigations- Civil Engineering-Structural- Road accidents -Fire accidents - Water related accidents-Electrical accidents and Investigation methods | 2 |
| 4.3 | Protocol for forensic Investigations-Standard guides-scope significance -use -procedures- reports. Standards – ASTM standards -FMV Standards -SAE Standards -Relevant Standards -NFPA Standards -International Standards | 1 |

| 5 | **Module 05: Engineer in the Court room& Criminal Cases (6 Hours)** | |
|---|---|---|
| 5.1 | Role of an Engineering Expert-Report-pre trial meetings-Alternative dispute resolution-Single joint expert. Engineer in the court room | 2 |
| 5.2 | Criminal Cases-Introduction-Counterfeit coins-fraudulent road accidents-Fraudulent Insurance claims. | 2 |
| 5.3 | Cyber Crimes and Cases- SIM Swapping -ATM Cloning-Microsoft Internal Spam- Intellectual property cases. | 2 |

**Reference Books**


1. Colin R Gagg, *Forensic EngineeringThe Art &Craft of a failure detective* , Taylor & Francis Publishing, 2020
2. Luca Fiorentini ,Luca Marmo *Principles of Forensic Engineering Applied to Industrial Accidents* , Wiley, 2019
3. Harold Franck, Darren Franck , *Forensic Engineering Fundamentals* ,Taylor & Francis publishing 2013
4. Randall K Noon , *Forensic Engineering Investigation*, CRC press limited , 2001
5. Stephen E Petty , *Forensic Engineering: Damage assessment for residential and commercial structures* CRC press 2nd edition , 2017
6. Joshua B Kardon , *Guideliness for forensic Engineering practice* , ASCE, 2012
7. Richard W. Mclay and Robert N. Anderson, *Engineering standards for forensic Applications* , Academic Press; 1st edition 2018
8. Max M Houck ,*Forensic Engineering (Advanced forensic Science ),* Academic press 1st edition 2017
9. Niranjan Reddy - Practical Cyber Forensics. *An Incident-based Approach to Forensic Investigations-Apress (2019)*
10. Peter Rhys Lewis, Ken Reynolds, Colin Gagg - *Forensic Materials Engineering Case Studies-CRC Press (2003) (1)*

## INTERNSHIP

A student shall opt for carrying out the Internship at an Industry/Research Organization or at another institute of higher learning and repute (Academia). The organization for Internship shall be selected/decided by the students on their own with prior approval from the faculty advisor/respective PG Programme Coordinator/Guide/Supervisor. Every student shall be assigned an internship Supervisor/Guide at the beginning of the Internship. The training shall be related to their specialisation after the second semester for a minimum duration of six to eight weeks. On completion of the course, the student is expected to be able to develop skills in facing and solving the problems experiencing in the related field.

### Objectives

- Exposure to the industrial environment, which cannot be simulated in the classroom and hence creating competent professionals for the industry.
- Provide possible opportunities to learn understand and sharpen the real time technical / managerial skills required at the job.
- Exposure to the current technological developments relevant to the subject area of training.
- Create conducive conditions with quest for knowledge and its applicability on the job.
- Understand the social, environmental, economic and administrative considerations that influence the working environment.
- Expose students to the engineer's responsibilities and ethics.

### Benefits of Internship

### Benefits to Students

- An opportunity to get hired by the Industry/ organization.
- Practical experience in an organizational setting & Industry environment.
- Excellent opportunity to see how the theoretical aspects learned in classes are integrated into the practical world. On-floor experience provides much more professional experience which is often worth more than classroom

teaching.

- Helps them decide if the industry and the profession is the best career option

  to pursue.
- Opportunity to learn new skills and supplement knowledge.
- Opportunity to practice communication and teamwork skills.
- Opportunity to learn strategies like time management, multi-tasking etc in an industrial setup.
- Makes a valuable addition to their resume.
- Enhances their candidacy for higher education/placement.
- Creating network and social circle and developing relationships with industry people.
- Provides opportunity to evaluate the organization before committing to a full time position.

**Benefits to the Institute**

- Build industry academia relations.
- Makes the placement process easier.
- Improve institutional credibility & branding.
- Helps in retention of the students.
- Curriculum revision can be made based on feedback from Industry/

  students.
- Improvement in teaching learning process.

**Benefits to the Industry**

- Availability of ready to contribute candidates for employment.
- Year round source of highly motivated pre-professionals.
- Students bring new perspectives to problem solving.
- Visibility of the organization is increased on campus.

- Quality candidate's availability for temporary or seasonal positions and projects.
- Freedom for industrial staff to pursue more creative projects.
- Availability of flexible, cost-effective workforce not requiring a long-term employer commitment.
- Proven, cost-effective way to recruit and evaluate potential employees.
- Enhancement of employer's image in the community by contributing to the educational enterprise.

**Types of Internships**

- Industry Internship with/without Stipend
- Govt / PSU Internship (BARC/Railway/ISRO etc)
- Internship with prominent education/research Institutes
- Internship with Incubation centres /Start-ups

**Guidelines**

- All the students need to go for internship for minimum duration of 6 to 8 weeks.
- Students can take mini projects, assignments, case studies by discussing it with concerned authority from industry and can work on it during internship.
- All students should compulsorily follow the rules and regulations as laid by industry.
- Every student should take prior permissions from concerned industrial authority if they want to use any drawings, photographs or any other document from industry.
- Student should follow all ethical practices and SOP of industry.
- Students have to take necessary health and safety precautions as laid by the industry.
- Student should contact his /her Guide/Supervisor from college on weekly basis to communicate the progress.
- Each student has to maintain a diary/log book
- After completion of internship, students are required to submit
    - Report of work done
    - Internship certificate copy
    - Feedback from employer / internship mentor
    - Stipend proof (in case of paid internship).

**Total Marks 100:** The marks awarded for the Internship will be on the basis of (i) Evaluation done by the Industry (ii) Students diary (iii) Internship Report and (iv) Comprehensive Viva Voce.

**Continuous Internal Evaluation: 50 marks**

| | | |
|---|---|---|
| Student's diary | - | 25 Marks |
| Evaluation done by the industry | - | 25 Marks |

**Student's Diary/ Daily Log**: The main purpose of writing daily diary is to cultivatethe habit of documenting and to encourage the students to search for details. It develops the students' thought process and reasoning abilities. The students should record in the daily training diary the day to day account of the observations, impressions, information gathered and suggestions given, if any. It should contain the sketches & drawings related to the observations made by the students. The daily training diary should be signed after every day by the supervisor/ in charge of the section where the student has been working. The diary should also be shown to the Faculty Mentor visiting the industry from time to time and got ratified on the day of his visit. Student's diary will be evaluated on the basis of the following criteria:

- Regularity in maintenance of the diary
- Adequacy & quality of information recorded
- Drawings, design, sketches and data recorded
- Thought process and recording techniques used
- Organization of the information.

**The format of student's diary**

Name of the Organization/Section:

Name and Address of the Section Head:

Name and Address of the Supervisor:

Name and address of the student:

Internship Duration: From ........................... To ..........................................

Brief description about the nature of internship:

| Day | Brief write up about the Activities carried out: Such as design, sketches, result observed, issues identified, data recorded, etc. |
|---|---|
| 1 | |
| 2 | |
| 3 | |

*Signature of Industry Supervisor* *Signature of Section Head/HR Manager*

*Office Seal*

## Attendance Sheet

Name of the Organization/Section:

Name and Address of the Section Head:

Name and Address of the Supervisor:

Name and address of the student:

Internship Duration: From ........................... To ..........................................

| Month & Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | ... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | | | | |
| Month & Year | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| Month & Year | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |

*Signature of Industry Supervisor* *Signature of Section Head/HR Manager*

*Office Seal*

**Note:**

- Student's Diary shall be submitted by the students along with attendance record and an evaluation sheet duly signed and stamped by the industry to the Institute immediately after the completion of the training.
- Attendance Sheet should remain affixed in daily training diary. Do not remove or tear it off.
- Student shall sign in the attendance column. Do not mark 'P'.
- Holidays should be marked in red ink in the attendance column. Absent should be marked as 'A' in red ink.

## Evaluation done by the Industry (Marks 25)

### Format for Supervisor Evaluation of Intern

Student Name :______________________________Date:___________________________

Supervisor Name :___________________________Designation:______________________

Company/Organization :_____________________________________________________

Internship Address: _________________________________________________________

Dates of Internship: From_____________________To ___________________________

***Please evaluate intern by indicating the frequency with which you observed the following parameters:***

| **Parameters** **Marks** | Needs improvement (0 – 0.25 mark) | Satisfactory (0.25 – 0.50 mark) | Good (0.75 mark) | Excellent (1 mark) |
|---|---|---|---|---|
| Behavior | | | | |
| Performs in a dependable Manner | | | | |
| Cooperates with coworkers and supervisor | | | | |
| Shows interest in work | | | | |
| Learns quickly | | | | |
| Shows initiative | | | | |
| Produces high quality work | | | | |
| Accepts responsibility | | | | |
| Accepts criticism | | | | |
| Demonstrates organizational skills | | | | |
| Uses technical knowledge and expertise | | | | |
| Shows good judgment | | | | |
| Demonstrates creativity/originality | | | | |
| Analyzes problems effectively | | | | |
| Is self-reliant | | | | |
| Communicates well | | | | |
| Writes effectively | | | | |
| Has a professional attitude | | | | |
| Gives a professional appearance | | | | |
| Is punctual | | | | |
| Uses time effectively | | | | |

Overall performance of student

Intern (Tick one) : Needs improvement (0 - 0.50 mark) / Satisfactory (0.50 – 1.0 mark) / Good (1.5 mark) / Excellent (2.0 mark)

Additional comments, if any (2 marks) :

*Signature of Industry Supervisor* *Signature of Section Head/HR Manager*

*Office Seal*

**End Semester Evaluation (External Evaluation): 50 Marks**

| | | |
|---|---|---|
| Internship Report | - | 25 Marks |
| Viva Voce | - | 25 Marks |

**Internship Report**: After completion of the internship, the student should prepare a comprehensive report to indicate what he has observed and learnt in the training period and should be submitted to the faculty Supervisor. The student may contact Industrial Supervisor/ Faculty Mentor for assigning special topics and problems and should prepare the final report on the assigned topics. Daily diary will also help to a great extent in writing the industrial report since much of the information has already been incorporated by the student into the daily diary. The training report should be signed by the Internship Supervisor, Programme Coordinator and Faculty Mentor.

The Internship report (25 Marks) will be evaluated on the basis of following criteria:

- Originality
- Adequacy and purposeful write-up
- Organization, format, drawings, sketches, style, language etc.
- Variety and relevance of learning experience
- Practical applications, relationships with basic theory and concepts taught in the course

Viva Voce (25 Marks) will be done by a committee comprising Faculty Supervisor, PG Programme Coordinator and an external expert (from Industry or research/academic Institute). This committee will be evaluating the internship report also.

## RESEARCH PROJECT/DISSERTATION

**Research Project:** Students choosing track 2 shall carry out the research project in their parent Institution only under the guidance of a supervisor assigned by the DLAC.

**Dissertation:** All categories of students in track 1 are to carry out the dissertation in the Institute they are studying or can work either in any CSIR/Industrial R&D organization/any other reputed Institute which have facilities for dissertation work in the area proposed.

**Mark Distribution:**

**Phase 1: Total marks: 100, only CIA**

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 223PXX100 | DISSERTATION PHASE I | Project Work | 0 | 0 | 17 | 11 |

**COURSE OBJECTIVES:**

Dissertation is aimed to bridge the gap between theoretical knowledge and practical application, fostering a well-rounded skill set that prepares students for success in their future engineering careers. Engineering projects often simulate real-world engineering scenarios. This exposure allows students to become familiar with industry practices, standards, and expectations and preparing them for the challenges they might face in their future careers. Depending on the nature of the project, students may acquire practical skills related to specific tools, software, or equipment. This hands-on experience can be highly beneficial when transitioning to a professional engineering role.

Dissertation Phase I can help to identify the problem based on the area of interest through proper literature survey and to foster innovation in design of products, processes or systems based on the identified problem. perform feasibility study by creative thinking and requirement analysis in finding viable solutions to engineering problems

All categories of students in track 1 are to carry out the dissertation in the Institute they are studying or in any CSIR/Industrial/ R&D organization/any other reputed institute which have facilities for dissertation work in the area proposed.

**Course Outcomes:**

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

| | |
|---|---|
| **CO 1** | Identify and define a relevant and significant problem or challenge in the relevant field |
| **CO2** | Formulate research methodologies for the innovative and creative solutions |
| **CO 3** | Plan and execute tasks utilizing available resources within timelines, following ethical professional and financial norms |
| **CO 4** | Organize and communicate technical and scientific findings effectively in written reports, oral presentation, and visual aids |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | 3 | | 3 | 2 | 2 | 3 | 2 |
| **CO 2** | 3 | | 3 | 3 | 3 | 2 | |
| **CO 3** | 3 | | 2 | | 3 | 3 | 2 |
| **CO 4** | | 3 | 3 | 2 | | | 2 |

**Continuous Internal Assessment (CIA) Total Marks: 100**

The evaluation committee comprises

1- Project Coordinator(s)
2- A Senior faculty member
3- Supervisor of the student

**Pattern:**

| | |
|---|---|
| Zeroth evaluation by the Evaluation Committee | - |
| Interim evaluation by the Evaluation Committee | 20 marks |
| Final evaluation by the Evaluation Committee | 40 marks |
| Project Phase - I Report (By Evaluation Committee) | 20 marks |
| Project progress evaluation by supervisor | 20 marks |

The Plagiarism level in the project report shall be less than 25%.

**Interim Review**

Literature Survey (CO1- 5 marks)
Comprehension and Problem Identification (CO2-5 marks)
Objective Identification (CO2-5 marks)
Document Preparation and Presentation (CO4-5 marks)

**Final Review**

Literature Survey (CO1-10 marks)
Project Design (CO2-10 marks)
Execution of tasks by utilizing available resources within timelines (CO3 – 10 marks)
Presentation and document preparation (CO4-10 marks)

**Evaluation by the supervisor**

The guide/supervisor shall monitor the progress being carried out by the student on a regular basis. In case it is found that progress is unsatisfactory it shall be reported to the Department Evaluation Committee for necessary action.

**Student's Diary/ Log book**: The main purpose of writing diary/log book is to cultivate the habit of documenting and to encourage the students to search for details. The activity diary shall be signed after every week by the supervisor.

The minimum attendance for completing the course is 75%. The pass minimum for the course is 50% for CIA.

**SYLLABUS:**

| DETAILS | HOURS |
|---|---|
| `<br>1. Literature study/survey of published literature on the assigned topic<br>2. Formulation of objectives<br>3. Formulation of hypothesis/ design/ methodology<br>4. Formulation of work plan and task allocation.<br>5. Design documentation<br>6. Preliminary analysis/Modelling/Simulation/Experiment/Design/Feasibility study<br>7. Preparation of Phase 1 report | 150 |

**Dissertation outside the Institute:** For doing dissertation outside the Institution, the following conditions are to be met:

i. They have completed successfully the course work prescribed in the approved curriculum up to the second semester.
ii. The student has to get prior approval from the DLAC and CLAC.
iii. Facilities required for doing the dissertation shall be available in the Organization/Industry (A certificate stating the facilities available in the proposed organization and the time period for which the facilities shall be made available to the student, issued by a competent authority from the Organization/Industry shall be submitted by the student along with the application).
iv. They should have an external as well as an internal supervisor. The internal supervisor should belong to the parent institution and the external supervisor should be Scientists or Engineers from the Institution/Industry/ R&D organization with which the student is associated for doing the dissertation work. The external supervisor shall be with a minimum post graduate degree in the related area.
v. The student has to furnish his /her monthly progress as well as attendance report signed by the external supervisor and submit the same to the concerned Internal supervisor.
vi. The external supervisor is to be preferably present during all the stages of evaluation of the dissertation.

**Internship leading to Dissertation:** The M. Tech students who after completion of 6 to 8 weeks internship at some reputed organizations are allowed to continue their work as dissertation for the third and fourth semester after getting approval from the CLAC. Such students shall make a brief presentation regarding the work they propose to carry out before the DLAC for a detailed scrutiny and to resolve its suitability for accepting it as an M.Tech dissertation. These students will be continuing as regular students of the Institute in third semester for carrying out all academic requirements as per the curriculum/regulation. However, they will be permitted to complete their dissertation in the Industry/Organization (where they have successfully completed their internship) during fourth semester. They should have an external as well as an internal supervisor. The internal supervisor should belong to the parent institution and the external supervisor should be Scientists or Engineers from the external organization with which the student is associated for doing the dissertation work. The external supervisor shall be with a minimum post graduate degree in the related area. The student has to furnish his /her monthly progress as well as attendance report signed by the external guide and submit the same to the concerned internal guide. The external guide is to be preferably present during all the stages of evaluation of the dissertation.

**Dissertation as part of Employment**: Students may be permitted to discontinue the programme and take up a job provided they have completed all the courses till second semester (FE status students are not permitted) prescribed in the approved curriculum. The dissertation work can be done during a later period either in the organization where they work if it has R&D facility, or in the Institute. Such students should submit application with details (copy of employment offer, plan of completion of their project etc.) to the Dean (PG) through HoD. The application shall be vetted by CLAC before granting the approval. When the students are planning to do the dissertation work in the organization with R&D facility where they are employed, they shall submit a separate application having following details:

i. Name of R&D Organization/Industry
ii. Name and designation of an external supervisor from the proposed Organization/Industry (Scientists or Engineers with a minimum post graduate degree in the related area) and his/her profile with consent
iii. Name and designation of a faculty member of the Institute as internal supervisor with his/her consent
iv. Letter from the competent authority from the Organization/Industry granting permission to do the dissertation
v. Details of the proposed work
vi. Work plan of completion of project

DLAC will scrutinize the proposal and forward to CLAC for approval. When students are doing dissertation work along with the job in the organization (with R & D facility) where they are employed, the dissertation work shall be completed in four semesters normally (two semesters of dissertation work along with the job may be considered as equivalent to one semester of dissertation work at the Institute). Extensions may be granted based on requests from the student and recommendation of the supervisors such that he/she will complete the M. Tech programme within four years from the date of admission as per the regulation. Method of assessment and grading of the dissertation will be the same as in the case of regular students. The course work in the 3rd semester for such students are to be completed as per the curriculum requirements (i) MOOC can be completed as per the norms mentioned earlier (ii) Audit course are to be carried out either in their parent Institution or by self-learning. However, for self-learning students, all assessments shall be carried out in their parent institution as in the case of regular students.

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| **224PXX100** | **DISSERTATION PHASE II** | **Project Work** | **0** | **0** | **24** | **16** |

All categories of students in track 1 are to carry out the DISSERTATION PHASE II in the institute they are studying or in any Industrial/ R&D organization/any other reputed institute which have facilities for dissertation work in the area proposed. DISSERTATION PHASE II shall not compulsorily continuation of DISSERTATION PHASE I. The student has to publish a research article in a conference or a reputed journal before appearing for the end-semester examination. The eligibility criteria for registering to the end semester examination are attendance in the course and no pending disciplinary action. The minimum attendance for appearing for the end semester examination is 75%. Students who do not meet these eligibility criteria are ineligible (identified by FE grade) to appear for the ESE. Students, who have completed a course but could not appear for the end semester examination, shall be awarded 'AB' Grade, provided they meet other eligibility criteria The pass minimum for the course is 45% for ESE and 50% for (CIA and ESE) put together.

**Continuous Internal Assessment (CIA) Total Marks: 100**

The evaluation committee comprises

1- Project Coordinator(s)
2- A Senior faculty member
3- Supervisor of the student

**Pattern (CIA)**

| | |
|---|---|
| Zeroth evaluation by the Evaluation Committee | - |
| Interim evaluation by the Evaluation Committee | 30 marks |
| Final evaluation by the Evaluation Committee | 50 marks |
| Project progress evaluation by supervisor | 20 marks |

**Evaluation by the supervisor**

The guide/supervisor shall monitor the progress being carried out by the student on a regular basis. In case it is found that progress is unsatisfactory it shall be reported to the Department Evaluation Committee for necessary action.

**Student's Diary/ Log book**: The main purpose of writing diary/log book is to cultivate the habit of documenting and to encourage the students to search for details. The activity diary shall be signed after every week by the supervisor.

**End Semester Evaluation (ESE) Total Marks: 100**

The evaluation committee comprises

1- Project Coordinator(s)
2- An external expert (from Industry or research/academic institute)
3- Supervisor of the student

**Pattern (ESE)**

1. **Innovation and Originality (10 marks):**
Assessment of the uniqueness and innovation demonstrated in the project work.
Original contributions, if any, to the field or problem area.
2. **Implementation and Execution (20 marks):**
Evaluation of the actual implementation or execution of the project, including:
    Quality of work done
    Demonstrated skills and techniques applied
    Adherence to project timelines and milestones
3. **Project Documentation (25 marks):**
Comprehensive project report evaluation including:
    Introduction and problem statement
    Literature review
    Methodology and approach
    Results and analysis
    Conclusion and recommendations
    References and citations
    Details of the publications
    Plagiarism certificate

The Plagiarism level in the project report shall be less than 25%.

4. **Presentation and Defence (40 marks):**
Oral presentation of the project to a panel of examiners, including:
    Clarity and effectiveness of the presentation
    Ability to explain the project objectives, methodologies, and findings
    Handling questions and providing satisfactory answers during the defence

5. **Publication of the work either in a conference or in a journal (5 marks)**

**SYLLABUS:**

| DETAILS | HOURS |
|---|---|
| `<br>1. Literature study/survey of published literature on the assigned topic<br>2. Topic Selection and Proposal<br>3. Formulation of objectives<br>4. Research and Planning<br>5. Formulation of work plan and task allocation.<br>6. Execution<br>7. Documentation and Reporting<br>8. Project Showcase reflecting on the project experience and lessons learned | 200 |

**Dissertation outside the Institute:** For doing dissertation outside the Institution, the following conditions are to be met:

i. They have completed successfully the course work prescribed in the approved curriculum up to the second semester.
ii. The student has to get prior approval from the DLAC and CLAC.
iii. Facilities required for doing the dissertation shall be available in the Organization/Industry (A certificate stating the facilities available in the proposed organization and the time period for which the facilities shall be made available to the student, issued by a competent authority from the Organization/Industry shall be submitted by the student along with the application).
iv. They should have an external as well as an internal supervisor. The internal supervisor should belong to the parent institution and the external supervisor should be Scientists or Engineers from the Institution/Industry/ R&D organization with which the student is associated for doing the dissertation work. The external supervisor shall be with a minimum post graduate degree in the related area.
v. The student has to furnish his /her monthly progress as well as attendance report signed by the external supervisor and submit the same to the concerned internal supervisor.
vi. The external supervisor is to be preferably present during all the stages of evaluation of the dissertation.