Group No.	Course Code	Course Title	UNIQUE CODE
1	20EPS12	Modelling and Analysis of Electrical Machines	201EE001
1	20EPS13	Power system Dynamics (Stability and Control)	201EE002
1	20EPS14	Computer Relaying for Power Systems	201EE003
1	20EPE12	Power Semiconductor Devices and Components	201EE004
1	20EPE22	Switched - Mode Power Supplies	201EE005
1	20ESE12	Energy Resources and the Environmental Impacts	201EE006
1	20ESE241	Solar Energy Technologies	201EE007
1	20ESE323	Energy Pricing – Economics and Principles	201EE008
1	20ESE333	Piezoelectric Energy	201EE009
1	20ESE321	Solar Hydrogen Energy Systems	201EE010
1	20ESE31	Energy Audit	201EE011
1	20EMS12	Analysis of Linear Systems	201EE012
1	20ECD242	Process Control and Instrumentation	201EE013
1	20EMS15	Industrial Control Technology - 1	201EE014
1	20EMS21	Optimal Control Theory	201EE015

2	20EPS15	Power Electronic Converters	202EE001
2	20EPS322	Power System Reliability	202EE002
2	20EPS254	Wind Energy Systems	202EE003
2	20EPS244	High-Power Battery Technologies	202EE004
2	20EPS334	Cybersecurity in the Electricity Sector	202EE005
2	20EPE14	Modelling and Design of Controllers	202EE006
2	20EPE242	Uninterruptible Power Supply	202EE007
2	20EPE243	Hybrid Electric Vehicles	202EE008
2	20ESE13	Energy Production, Conversion and Conservation	202EE009
2	20ESE242	Photovoltaics	202EE010
2	20ESE15	Power System Operation	202EE011
2	20ESE322	Energy Management Strategies for EV/PHEV	202EE012
2	20EMS13	VLSI Design	202EE013
2	20EMS31	Industrial Control Technology – 2	202EE014
2	20EMS322	Digital System Design with FPGA	202EE015

3	20EPS323	Wide Area Measurements and their Applications	203EE001
3	20EPS324	Data Analytics for the Smart Grid	203EE002
3	20EPE322	EMC in Power Electronics	203EE003
3	20EPE323	Multilevel Converters for Industrial Applications	203EE004
3	20EPE241	Converters for Solar and Wind Power Systems	203EE005
3	20EPE244	Neural and Fuzzy Logic Control of Drives	203EE006
3	20ECD14	AC and DC Drives – 1	203EE007
3	20ESE14	Energy Conversion Technologies	203EE008
3	20ESE243	Introduction to Nuclear Power	203EE009
3	20ESE253	Carbon Capture and Storage	203EE010
3	20ESE331	Energy Storage in Power Grids	203EE011
3	20EMS241	Nonlinear Systems	203EE012
3	20EMS243	Control Systems for HVAC	203EE013
3	20EMS333	Nanotechnology for Microelectronics and Optoelectronics	203EE014
3	20EMS331	Microelectronic Fabrication	203EE015

4	20EPS243	Restructured Power Systems	204EE001
4	20EPS333	Substation Automation Systems	204EE002
4	20EPS332	Integration of Renewable Energy	204EE003
4	20EPS21	EHV AC Transmission.	204EE004
4	20EPE21	Electric Drives	204EE005
4	20ECD21	AC and DC Drives – 2	204EE006
4	20ECD331	PLC Applications in Electric Drives	204EE007
4	20ECD252	Electric Drive Design	204EE008
4	20ECD323	Sensorless AC Motor Control	204EE009
4	20ESE21	Integration of Distributed Generation	204EE010
4	20ESE244	Environmental Impacts of Renewable Energy	204EE011
4	20EMS22	High Speed VLSI Design	204EE012
4	20EMS252	Robust Control Theory	204EE013
4	20EMS251	Reset Control Systems	204EE014
4	20EMS321	Industrial control: Software and Routines	204EE015

5	20EPS242	Power System Harmonics	205EE001
5	20EPS252	Power System Voltage Stability	205EE002
5	20EPS241	Insulators for Power System	205EE003
5	20EPS22	Switching in Power Systems	205EE004
5	20EPS331	Smart Grid	205EE005
5	20EPE321	MPPT in Solar Systems	205EE006
5	20EPE331	Advanced Control Systems	205EE007
5	20ECD241	Special Electrical Machines	205EE008
5	20ECD22	DSP Applications to Drives	205EE009
5	20ECD333	Sneak Circuits in Converters	205EE010
5	20ESE22	Industrial Energy and Management	205EE011
5	20ESE254	Intelligent Energy Demand Forecasting	205EE012
5	20EMS23	CAD Tools For VLSI Design	205EE013
5	20EMS253	Digital System Design with VHDL	205EE014

6	20EPS251	Linear and Nonlinear Optimization	206EE001
6	20EPS23	FACTS Controllers	206EE002
6	20EPS253	Power Quality Problems and Mitigation	206EE003
6	20EPS31	HVDC Power Transmission	206EE004
6	20EPS321	Multi-Terminal DC Grids	206EE005
6	20EPE253	Embedded Systems	206EE006
6	20EPE252	Digital Power Electronics	206EE007
6	20EPE254	Internet-Based Control Systems	206EE008
6	20ECD251	Predictive Control of Drives	206EE009
6	20ECD332	AC drives with inverter Output Filters	206EE010
6	20ECD322	FPGA and Programmable Logic	206EE011
6	20ESE23	Power System Planning	206EE012
6	20EMS332	Low Power VLSI(very Large Scale Integration) Design	206EE013
6	20EMS323	Real Time Approach to Process Control	206EE014

(Group-1): 20EPS12 Modelling and Analysis of Electrical Machines

Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Basic Concepts of Modelling: Basic two pole machine representation of commutator machines, 3-phase synchronous machine with and without damper bar and 3-phase induction machine, Kron's primitive machine-voltage, current and torque equations.

DC Machine Modelling: Mathematical model of separately excited DC motor-steady state and transient state analysis, sudden application of inertia load, transfer function of separately excited DC motor, mathematical model of dc series motor, shunt motor, linearization techniques for small perturbations.■

Module-2

Reference Frame Theory: Real time model of a two phase induction machine, transformation to obtain constant matrices, three phase to two phase transformation, power equivalence.

Dynamic Modelling of Three Phase Induction Machine: Generalized model in arbitrary frame, electromagnetic torque, deviation of commonly used induction motor models-stator reference frames model, rotor reference frames model, synchronously rotating reference frames model, equations in flux linkages, per unit model, dynamic simulation. ■

Module-3

Small Signal Equations of the Induction Machine: Derivation of small signal equations of induction machine, space phasor model, DQ flux linkages model derivation, control principle of the induction motor.

Transformer Modelling: Introduction, single phase transformer model, three phase transformer connections, per phase analysis, normal systems, per unit normalization, per unit three phase quantities, change of base, per unit analysis of normal system, regulating transformers for voltage and phase angle control, auto transformers, transmission line and transformers. ■

Module-4

Modelling of Synchronous Machines: Introduction, voltage equations and torque equation in machine variables, stator voltage equations in arbitrary and rotor reference frame variables, Park's equations, torque equations in substitute variables, rotor angle and angle between rotors, per unit system, analysis of steady state operation. ■

Module-5

Dynamic Analysis of Synchronous Machines: Dynamic performance during sudden change in input torque and during a 3-phase fault at the machine terminals, approximate transient torque versus rotor angle characteristics, comparison of actual and approximate transient torque-angle characteristics during a sudden change in input torque; first swing transient stability limit, comparison of actual and approximate transient torque-angle characteristics during a 3-phase fault at the machine terminals, critical clearing time, equal area criterion, computer simulation. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

1	Generalized Theory of Electrical Machines	P.S.Bimbra	Khanna Publications	5th Edition,1995
2	Electric Motor Drives - Modelling, Analysis & Control	R. Krishnan	PHI Learning Private Ltd	Indian Edition, 2009
3	Analysis of Electrical Machinery and Drive Systems	P.C.Krause, et al	Wiley	2nd Edition,2010
4	Power System Analysis	Arthur R Bergen e tal	Pearson	2nd Edition,2009
5	Power System Stability and Control	Prabha Kundur	Mc Graw Hill	1st Edition,1994
6	Dynamic Simulation of Electric Machinery using Matlab / Simulink	Chee-Mun Ong	Prentice Hall	1998

(Group-1): 20EPS13 Power system Dynamics (Stability and Control)

Exam Hours: 3 hours | **Exam Marks(Maximum):100**

Module-1

Basic Concepts of Power System: Introduction, Power System Stability, States of Operation and System Security, System Dynamic Problems.
Analysis of system stability: System Model, Mathematical Preliminaries, Analysis of Steady State Stability and Transient Stability, Excitation Control.
Modelling of Synchronous Machine: Introduction, Synchronous Machine, Park's Transformation, Analysis of Steady State Performance, Per Unit Quantities. ■

Module-2

Modelling of Synchronous Machine (continued): Equivalent Circuits of Synchronous Machine, Determination of Parameters of Equivalent Circuits, Measurements for obtaining Data, Saturation Models, Transient Analysis of a Synchronous Machine, Power System Dynamics - Stability and Control.
Excitation and Prime Mover Controllers: Excitation System, Excitation System Modelling, Excitation Systems-Standard Block Diagram, System Representation by State Equations, Prime-Mover Control System. ■

Module-3

Transmission Lines, SVC and Loads: Transmission Lines, D-Q Transformation using alpha and beta Variables), Static Var compensators, Loads.
Dynamics of a Synchronous Generator Connected to Infinite Bus: System Model, Synchronous Machine Model, Application of Model 1.1, Calculation of Initial Conditions, System Simulation, Consideration of other Machine Models. Inclusion of SVC Model. ■

Module-4

Analysis of Single Machine System: Small Signal Analysis with Block Diagram Representation, Characteristic Equation and Application of Routh-Hurwitz Criterion, Synchronizing and Damping Torques Analysis, Small Signal Model: State Equations, Nonlinear Oscillations - Hopf Bifurcation.
Application of Power System Stabilizers: Introduction, Basic concepts in applying PSS, Control Signals, Structure and tuning of PSS, Field implementation and operating experience, Examples of PSS Design and Application. ■

Module-5

Analysis of Multimachine System: A Simplified System Model, Detailed Models: Case I and Case II, Inclusion of Load and SVC Dynamics, Modal Analysis of Large Power Systems, Case Studies.
Simulation for Transient Stability Evaluation: Mathematical Formulation, Solution Methods, Formulation of System Equations, Solution of System Equations, Simultaneous Solution, Case Studies, Dynamic Equivalents and Model Reduction. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

1	Power System Dynamics Stability and Control	K.R. Padiyar	B.S. Publications	2nd Edition,2008
2	Power system control and stability	P.M. Anderson et al	B.S. Publications	2nd Edition,2003
3	Power System Dynamics and Stability	Peter W. Sauer et al	PHI	1st Edition, 1998

(Group-1): 20EPS14 Computer Relaying for Power Systems

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Introduction to computer relaying: Development of computer relaying, historical background , expected benefits of computer relaying, computer relay architecture, analog to digital converters, anti-aliasing filters, substation computer hierarchy.
Relaying practices: Introduction to protection systems, functions of a protection system, protection of transmission lines, transformer, reactor and generator protection, bus protection, performance of current and voltage transformers. ■

Module-2

Mathematical basis for protective relaying algorithms: Introduction, Fourier series, other orthogonal expansions, Fourier transforms, use of Fourier transforms, discrete Fourier transform, introduction to probability and random process, random processes, Kalman filtering.
Digital filters: Introduction, discrete time systems, discrete time systems, Z Transforms, digital filters, windows and windowing, linear phase, Approximation – filter synthesis, wavelets, elements of artificial intelligence. ■

Module-3

Transmission line relaying: Introduction, sources of error, relaying as parameter estimation, beyond parameter estimation, symmetrical component distance relay, newer analytic techniques, protection of series compensated .
Protection of transformers, machines and buses: Introduction, power transformer algorithms, generator protection, motor protection, digital bus protection. ■

Module-4

Hardware organization in integrated systems: The nature of hardware issues, computers for relaying, the substation environment, industry environmental standards, countermeasures against EMI, supplementary equipment, redundancy and backup, servicing, training and maintenance.
System relaying and control: Introduction, measurement of frequency and phase, sampling clock synchronization, application of phasor measurements to state estimation, phasor measurements in dynamic state estimation, monitoring, control applications. ■

Module-5

Relaying applications of traveling waves: Introduction, traveling waves on single-phase lines, traveling waves on three-phase lines, directional wave relay, traveling wave distance relay, differential relaying with phasors, traveling wave differential relays, fault location, other recent developments.
Wide area measurement applications: Adaptive relaying, examples of adaptive relaying, wide area measurement systems (WAMS), WAMS architecture, WAMS based protection concepts. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Computer Relaying for Power Systems	Arun G. Phadke, James S. Thorp	Wiley	2nd Edition,2009

(Group-1): 20EPE12 Power Semiconductor Devices and Components

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Power Electronics: Introduction, Converter Classification, Power Electronics Concepts, Electronic Switches, Switch Selection, Spice, PSpice and Capture, Representation of switches in Pspice -The Voltage-Controlled Switch, Transistors, Diodes and Thyristors (SCRs).
Power Computations: Introduction, Power and Energy, Inductors and Capacitors, Energy Recovery, Effective Values, Apparent Power and Power Factor, Power Computations for Sinusoidal AC Circuits, Power Computations for Nonsinusoidal Periodic Waveforms, Power Computations Using Pspice.
Basic Semiconductor Physics: Introduction, Conduction Processes in Semiconductors
pn Junctions, Charge Control Description of pn-Junction Operation, Avalanche Breakdown. ■

Module-2

Power Diodes: Introduction, Basic Structure and I – V characteristics, Breakdown Voltage Considerations, On – State Losses, Switching Characteristics, Schottky Diodes.
Bipolar Junction Transistors: Introduction, Vertical Power Transistor Structures, Z-V Characteristics, Physics of BJT Operation, Switching Characteristics, Breakdown Voltages, Second Breakdown, On-State Losses, Safe Operating areas.
Power MOSFETs: Introduction, Basic Structure, I-V Characteristics, Physics of Device Operation, Switching Characteristics, Operating Limitations and Safe Operating Areas. ■

Module-3

Thyristors: Introduction, Basic Structure, I-V Characteristics, Physics of Device Operation, Switching Characteristics, Methods of Improving di/dt and dv/dt Ratings.
Gate Turn-Off Thyristors: Introduction, Basic Structure and Z-V Characteristics,
Physics of Turn-Off Operation, GTO Switching Characteristics, Overcurrent Protection of GTOs.
Insulated Gate Bipolar Transistors: Introduction, Basic Structure, I-V Characteristics, Physics of Device Operation, Latchup in IGBTs, Switching Characteristics, Device Limits and SOAs.
Emerging Devices and Circuits: Introduction, Power Junction Field Effect Transistors, Field-Controlled Thyristor, JFET-Based Devices versus Other Power Devices, MOS-Controlled Thyristors, Power Integrated Circuits, New Semiconductor Materials for Power Devices. ■

Module-4

Snubber Circuits: Function and Types of Snubber Circuits, Diode Snubbers, Snubber Circuits for Thyristors, Need for Snubbers with Transistors, Turn-Off Snubber, Overvoltage Snubber, Turn-On Snubber, Snubbers for Bridge Circuit Configurations, GTO Snubber Considerations.
Gate and Base Drive Circuits: Preliminary Design Considerations, dc-Coupled Drive Circuits, Electrically Isolated Drive Circuits, Cascode-Connected Drive Circuits, Thyristor Drive Circuits, Power Device Protection in Drive Circuits, Circuit Layout Considerations ■

Module-5

Component Temperature Control and Heat Sinks: Control of Semiconductor Device Temperatures, Heat Transfer by Conduction, Heat sinks, Heat Transfer by Radiation and Convection.
Design of Magnetic Components: Magnetic Materials and Cores, Copper Windings, Thermal Considerations, Analysis of a Specific Inductor Design, Inductor Design Procedures, Analysis of a Specific Transformer Design, Eddy Currents, Transformer Leakage Inductance, Transformer Design Procedure, Comparison of Transformer and Inductor Sizes. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

1	Power Electronics	Daniel W Hart	McGraw Hill	
2	Power Electronics Converters, Applications, and Design	Ned Mohan et al	Wiley	3rd Edition,2014
3	Semiconductor Device Modeling with Spice	G. Massobrio et al	McGraw-Hill	2nd Edition, 2010
4	Power Semiconductor Devices	B. Jayant Baliga	Springer	2008

(Group-1): 20EPE22 Switched - Mode Power Supplies

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Switching-Mode Power Supply (SMPS): Overview, Classification of Integrated Regulated Power Supply, Characteristics of SMPS, New Development Trend of SMPS, Basic Principles of SMPS, Control Mode Type of SMPS, Working Mode of SMPS, Feedback Type of SMPS, Load Characteristics of SMPS.
Topologies of the DC/DC Converter: Topologies of the DC/DC Converter, Basic Principle of Buck Converter, Basic Principle of - Boost Converter, Buck-Boost Converter, Charge Pump Converter, (Single-ended primary inductor converter)SEPIC, Flyback Converter, Forward Converter, Push-Pull Converter, Half/Full Bridge Converter, Soft Switching Converter, Half-Bridge LLC Resonant Converter,2-Switch Forward Converter. ■

Module-2

Method for Selecting Key Peripheral Components of SMPS: Selection Method for - Fixed Resistor, Capacitors, Inductor Characteristics and Selection Method for Magnetic Beads, Selection Method for EMI Filter - Input Bridge Rectifier, Output Rectifier, Transient Voltage Suppressor (TVS), Power Switching Tube, Optical Coupler, Adjustable Precision Shunt Regulator, SMPS Protection Elements. ■

Module-3

Power Factor Correction Circuit Design of SMPS: Brief Introduction to Power Factor Correction (PFC), Basic Principle of Passive PFC Circuit, Design Examples of Passive PFC Circuit, Basic Principle of Active PFC Circuit, Design Examples of Active PFC Circuit, Principle and Application of High-Power PFC, Measures to Suppress PFC Electromagnetic Interference, PFC Configuration Scheme.
Design of High-Frequency Transformer: Selection Method for Magnetic Cores by the Empirical Formula or Output Power Table, Waveform Parameters of the High-Frequency Transformer Circuit, Formula Derivation of Selecting High-Frequency Transformer Magnetic Core Based on AP Method, Design of Flyback High-Frequency Transformer, Design of Forward High-Frequency Transformer, Loss of High-Frequency Transformer. ■

Module-4

Key Design Points of SMPS: SMPS Design Requirements, Design of High-Efficiency SMPS, Methods of Reducing No-Load and Standby Power Consumption of SMPS, Stability Design of Optocoupler Feedback Control Loop SMPS Layout and Wiring, Design of Constant Voltage/Current SMPS, Design of Precision Constant Voltage/Current SMPS, Design of Remote Turn-Off Circuit for SMPS,Typical Application and Printed Circuit Design of New Single-Chip SMPS, Electromagnetic Interference Waveform Analysis and Safety Code Design of SMPS, Radiator Design of Single-Chip SMPS, Radiator Design of Power Switching Tube (MOSFET), Common Troubleshooting Methods of SMPS. ■

Module-5

SMPS Testing Technology: Parameter Testing of SMPS, Performance Testing of SMPS, SMPS Measurement Skills, Accurate Measurement Method of Duty Ratio, Method to Detect the Magnetic Saturation of High-Frequency Transformer with Oscilloscope, Digital Online Current/Resistance Meter, Electromagnetic Compatibility Measurement of SMPS, Waveform Test and Analysis of SMPS.
Protection and Monitoring Circuit Design of SMPS: Design of Drain Clamp Protection Circuit, Overvoltage Protection Circuit Constituted by Discrete Components, Application of Integrated Overvoltage Protector, Design of Undervoltage Protection Circuit, Design of Overcurrent and Overpower Protection Circuit, Design of Soft-Start Circuit, Mains Voltage Monitor, Transient Interference and Audio Noise Suppression Technology of SMPS, Design of Overheating Protection Component and Cooling Control System. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Optimal Design of Switching Power Supply	Zhanyou Sha et al	Wiley	2015

(Group-1): 20ESE12 Energy Resources and the Environmental Impacts

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Energy Issues: Introduction, Energy Terms, Conservation Law for Energy, Enthalpy, Heat Transfer, Net Energy Analysis, Developing a National Energy Policy.
Thermodynamic Principles: Introduction, Qualitative Review of the Second Law, Describing Equations, The Heat Exchanger Dilemma, Applications.
Energy Demand: Introduction, Early History, The First Humans, The Industrial Revolution, Recent Years, Effect of Demand of Energy Resources, Canada, Energy Needs, Energy Resources, Tar Sands, Future Energy Demands.
Sustainability and Green Science/Engineering: Introduction, Sustainability, Green Science/ Engineering. ■

Module-2

Energy Regulations: Introduction, The Regulatory System, Laws and Regulations: The Differences, The Role of the States, The Department of Energy (DOE), The Federal Energy Regulatory Commission (FERC), Energy Information Administration (EIA), The Environmental Protection Agency (EPA), The 2013 New York State Energy Plan, Overview of New York's State Energy Plan.
The Modern Energy Matrix: Introduction, Energy System Components, Energy Matrix Overview.
Energy Resources – (a) Coal: Introduction, Early History, Availability/Distribution and Characterization, Extraction, Processing, and Transportation/ Transmission, Environmental Issues, Future Prospects and Concerns. ■

Module-3

Energy Resources (continued)
(b) Oil, (c) Natural Gas, (d) Shale Oil, (e) Tar Sands, (f) Solar Energy: Introduction, Early History, Availability/Distribution and Characterization, Extraction, Processing, and Transportation/ Transmission, Environmental Issues, Future Prospects and Concerns. ■

Module-4

Energy Resources (continued)
(g)Nuclear Energy, (i) Hydroelectric Energy, (j) Wind Energy (k) Geothermal Energy (l) Hydrogen Energy, (m) Biomass Energy: Introduction, Early History, Availability/Distribution and Characterization, Extraction, Conversion, and Transportation/ Transmission, Environmental Issues, Future Prospects and Concerns. ■

Module-5

Other Energy Sources: Introduction, Fuels Derived from Coals and Oils, Hydrocarbons, Hydrokinetic Energy, Ocean Thermal Energy, Wave Energy.
Energy Demand and Distribution Systems: Introduction, The Evolution of Energy Demand, Energy Stakeholders, The Role of Distribution Systems.
Conservation, Sustainability, and Green Engineering: Introduction, Energy Conservation, Sustainability Approaches, Green Engineering.
Environmental Considerations: Introduction, Environmental Management Topics, Environmental Factors, The Health Risk Evaluation Process, The Hazard Risk Assessment Process.
Economic Considerations: Introduction, Operating Costs, Energy Cost Data, Hidden Economic Factors, Project Evaluation and Optimization, Principles of Accounting, Concluding Remarks. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.

Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Energy Resources Availability, Management, and Environmental Impacts.	Kenneth J. Skipka, Louis Theodore	CRC Press	2014

(Group-1): 20ESE241 Solar Energy Technologies	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Solar Energy: History and Current Use, Advantages of Solar Energy, Solar Energy Project Delivery Process, Integration of Solar Energy into the Existing Infrastructure.
Solar Energy Resource: Structure of the Sun, Nuclear Fusion: The Source of the Sun's Power, The Spectral Nature of Solar Radiation, Position of the Sun in the Sky, Direct Beam, Diffuse, and Global Solar Insolation in the Plane of a Solar Collector Surface, Incident Angle of Direct Beam Sun on a Surface, The Effect of Shade, Solar Resource Measurement, Solar Resource Maps and Data, Typical Meteorological Year (TMY) Weather Data, Forecasting the Solar Resource Hours or Days into the Future, Diagnosis of Solar Energy System Performance Using Solar Resource Data, Computer Tools for Analysis of Solar Position and Solar Resources, Standards Related to Solar Resource Assessment. ■

Module-2

Photovoltaics (PV, Solar Electricity): Photovoltaic Cells and Modules, Voltage and Current Characteristics of PV Devices (the *i-v* curve), Open-Circuit Voltage and Operating Voltage of a PV Cell, Dependence of Voltage and Current on Temperature, Different Types of Photovoltaic Devices, Standard Ratings and Performance Indicators for PV Modules, Energy Balance for a PV Module, Nominal Operating cell Temperature (NOCT), Power Output of a PV Module, Photovoltaic System Schematic Design, Photovoltaic System Components, Estimating the Cost of a Photovoltaic System, Estimating Electric Use and Solar Fraction, Recommended Applications, Simple Hand Calculation of Photovoltaic System Size and Energy Delivery, Estimating the Energy Cost Savings of a Photovoltaic (Solar Electric) System, Computer Tools for Analysis of Photovoltaic Systems, Codes and Standards for Photovoltaic Modules and Systems, Operation and Maintenance of Photovoltaic Systems, Case Studies of Photovoltaic System Installations Procurement Specifications for Grid-Tied Solar Electric (Photovoltaic) System. ■

Module-3

Solar Water Heating: Different Types of Water-Heating, Solar Collectors, Solar Water Heating System Schematic Design, Solar Water Heating System Components, Estimating the Cost of a Solar Water Heating System, Estimating Building Hot Water Use and Solar Fraction, Recommended Applications, Simple Hand Calculation of Solar Water Heating System Size and Energy Delivery, System Thermodynamics and Computer Tools for Analysis of Solar Water Heating Systems, Codes and Standards for Solar Water Heaters, Operation and Maintenance of Solar Water Heating Systems, Case Studies of Solar Water Heating System Installations, Procurement Specifications for a Solar Water Heating System. ■

Module-4

Solar Ventilation Air Preheating: Operating Principle of the Transpired Air-Heating
Solar Collector, Solar Ventilation Air Preheat System Schematic, Solar Ventilation Air Preheat System Components, Design Considerations, Recommended Applications, Estimating the Cost of a Solar Ventilation Air Preheat System, Simple Hand Calculations for Size and Performance of a Solar Ventilation Air Heating System, Computer Tools for Analysis of Solar Ventilation Preheat Systems, Codes and Standards related to Solar Ventilation Air Preheating, Maintenance of Solar Ventilation Air Preheating Systems, Case Studies of Solar Ventilation Air Preheating System Installations, Procurement Specifications for Solar Ventilation Preheat System. ■

Module-5

Solar Space Heating and Cooling: Site Issues, Building Heat Loss, Solar Heat Gain through Windows and Opaque Surfaces, Materials and Building Components for Passive Solar Space Heating Systems, Thermal Storage, Heat Distribution Systems, Solar Space Heating (Passive or Active), System Schematic Design, Estimating the Cost of a Solar Space Heating System, Estimating Energy Use and Solar Fraction, Calculation of Solar Space Heating System Sizing and Energy Delivery, Computer Tools for Analysis of Passive Solar Systems, Codes and Standards Related to Passive Solar Heating, Operation and Maintenance of Passive Solar heating Systems, Case Studies of Passive Solar Space Heating Systems, Procurement Specifications for Passive Solar Thermal Storage Wall. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook				
1	Solar Energy Technologies and the Project Delivery Process for Buildings	Andy Walker	Wiley	2013

(Group-1): 20ESE323 Energy Pricing – Economics and Principles

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Introduction: Distinguishing Between Cost and Price, Cost and Price in Our Daily Vocabulary, The Credibility of Cost, Total Cost of the Operation as a Whole, Joint-Product Costs, Price Relationships: The Baker Revisited - The Quantity Discount, The Economics of Fixed (Overhead) Costs, A Closer Look at Two-Part Pricing, Competitive Pricing (Value to the Purchaser), From Wonderland to Reality, Cost and Price-A Primer.

The Cost Approach to Pricing-The Direction of Cost: Preface, Fixed and Variable Costs, Decreasing, Constant, and Increasing Costs Conditions, Decreasing Costs, The Base System, Future Additions, The Small Base-Load Plant, The Peaking or Firming-Up Plant, Power Purchases by Electric Utilities from Non-utility Sources, Bypass, and Discounts, Variable Costs, Matters of Judgment, A Note on Generating Plants, A Note on the Level of Costs. ■

Module-2

The Cost Approach to Pricing - Joint Cost Allocations: Direct and Joint/Common Costs,
Cost Causation, Utility Cost Allocation Theory, The Functionalization of Costs, Methods of Allocation, Distribution, Rate Schedule Divisions of Cost, Suballocations, The Total Cost and Incremental Cost Methods, The Separable Costs-Remaining Benefits Method of Cost Allocation in Federal Multi-purpose Projects, Limits on the Ascertainment of Costs,
Definitions of Cost.

The Cost Approach to Pricing - The Tenneco Pattern: Tenneco Pattern, The Issues, The Regulatory Scheme in Brief, Assignment of Fixed and Variable Costs, The Demand Charge, Zoning, A Resume, The Minimum Bill, Tenneco Allocations for Rate Design. ■

Module-3

The Value Approach to Pricing - Demand Influence: Preface, Value of Service Defined, Cost vs. Value in Juxtaposition, The "Upper and Lower Limit of Rates" Concept, Economic Demand, Direct and Derived Demand, Option Demand, The Price Elasticity of Demand, The Crucial Importance of Price Elasticity, The Revenue Effects of Elasticity, Immediate, Short-Run and Long-Run Price Elasticities of Demand, Repression and Stimulation, The Principle of Diminishing Utility, Economics of Pricing on a Value of Service Basis, Monopoly Pricing, The Theory of Class Price, Bases of Rate Classes, The Cost and Value Approaches Compared, Unreasonable Discrimination, Predatory Pricing, Is There a Problem?, Concluding Observations on Cost vs. Value, Marketing and Advertising.

The Value Approach to Pricing - Planning for Demand: Units of Measurement, Procedure, Planning: Short-Run Demand Forecasts, Planning: Long-Range Demand Forecasts, Final Results, Public Policy Forecasts, Concluding Comments. ■

Module-4

The Public Policy/Social Engineering Approach to Pricing: California's Lifeline/ Baseline Rate, Cost Components of Rates, Timed Pricing, The Colour GREEN, Venture into Marginal Cost Regulation, Wind Rates on an Integrated Electric System.

Introduction to Rates: The Unregulated Marketplace, The Marketplace Under Regulation,
The Customer Viewpoint, The Management Viewpoint, The Public Viewpoint, Related Objectives, Some Expert Opinions, Definitions.

Elements of Rate Design: Frequent Features, The "Blocking" Principle, "Postage Stamp" vs. Zone Rates, All-Purpose vs. Special-Purpose Rates: Unbundling, Seasonal vs. Year-Round Rates, Rolled-in vs. Incremental Pricing/Old Customer vs. New Customer Rates, Rate-Level Changes Across-the-Board, The "Fine-Print" Provisions, Nota Bene. ■

Module-5

Traditional Types of Rate Forms: Introduction, Rate Elements Defined Again,
Single-Part Rate Forms, Two-Part Rate Forms, Three-Part Rate Forms, Modifications of Rate Forms and Special Applications, Miscellany.

Tools of the Trade: Introduction, Knowing the Market: Load Curves, Gauging the Market: Analysis Factors, Capacity Factor, Utilization Factor, Demand Factor, Power Factor, A Note to the Rate maker. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Energy Pricing - Economics and Principles	Roger L. Conkling	Springer	2011

(Group-1): 20ESE333 Piezoelectric Energy	
Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Introduction to Piezoelectric Energy Harvesting: Vibration-Based Energy Harvesting Using Piezoelectric Transduction, An Example of a Piezoelectric Energy Harvesting System, Mathematical Modelling of Piezoelectric Energy Harvesters.

Base Excitation Problem for Cantilevered Structures and Correction of the Lumped-Parameter Electromechanical Model: Base Excitation Problem for the Transverse Vibrations of a Cantilevered Thin Beam, Correction of the Lumped-Parameter Base Excitation Model for Transverse Vibrations, Experimental Case Studies for Validation of the Correction Factor, Base Excitation Problem for Longitudinal Vibrations and Correction of its Lumped-Parameter Model, Correction Factor in the Electromechanically Coupled Lumped-Parameter Equations and a Theoretical Case Study. ■

Module-2

Analytical Distributed-Parameter Electromechanical Modelling of Cantilevered Piezoelectric Energy Harvesters: Fundamentals of the Electromechanically Coupled Distributed-Parameter Model, Series Connection of the Piezoceramic Layers, Parallel Connection of the Piezoceramic Layers, Equivalent Representation of the Series and the Parallel Connection Cases, Single-Mode Electromechanical Equations for Modal Excitations, Multi-mode and Single-Mode Electromechanical FRFs, Theoretical Case Study.■

Module-3

Experimental Validation of the Analytical Solution for Bimorph Configurations: PZT-5H Bimorph Cantilever without a Tip Mass, PZT-5H Bimorph Cantilever with a Tip Mass, PZT-5A Bimorph Cantilever.

Dimensionless Equations, Asymptotic Analyses, and Closed-Form Relations for Parameter Identification and Optimization: Dimensionless Representation of the Single-Mode Electromechanical FRFs, Asymptotic Analyses and Resonance Frequencies, Identification of Mechanical Damping, Identification of the Optimum Electrical Load for Resonance Excitation,

Identification and Optimization(continued): Intersection of the Voltage Asymptotes and a Simple Technique for the Experimental Identification of the Optimum Load Resistance, Vibration Attenuation/Amplification from the Short-Circuit to Open-Circuit Conditions, Experimental Validation for a PZT-5H Bimorph Cantilever. ■

Module-4

Approximate Analytical Distributed-Parameter Electromechanical Modelling of Cantilevered Piezoelectric Energy Harvesters: Unimorph Piezoelectric Energy Harvester Configuration, Electromechanical Euler–Bernoulli Model with Axial Deformations, Electromechanical Rayleigh Model with Axial Deformations, Electromechanical Timoshenko Model with Axial Deformations, Modelling of Symmetric Configurations, Presence of a Tip Mass in the Euler–Bernoulli, Rayleigh,

Approximate Analytical Distributed-Parameter Electromechanical Modelling of Cantilevered Piezoelectric Energy Harvesters (continued): and Timoshenko Models, Comments on the Kinematically Admissible Trial Functions, Experimental Validation of the Assumed-Modes Solution for a Bimorph Cantilever, Experimental Validation for a Two-Segment Cantilever.

Modelling of Piezoelectric Energy Harvesting for Various Forms of Dynamic Loading: Governing Electromechanical Equations, Periodic Excitation, White Noise Excitation, Excitation Due to Moving Loads, Local Strain Fluctuations on Large Structures, Numerical Solution for General Transient Excitation, Case Studies.■

Module-5

Modelling and Exploiting Mechanical Nonlinearities in Piezoelectric Energy Harvesting: Perturbation Solution of the Piezoelectric Energy Harvesting Problem: the Method of Multiple Scales, Monostable Duffing Oscillator with Piezoelectric Coupling, Bistable Duffing Oscillator with Piezoelectric Coupling: the Piezomagnetoelastic Energy Harvester, Experimental Performance Results of the Bistable Piezomagnetoelastic Energy Harvester, A Bistable Plate for Piezoelectric Energy Harvesting.

Piezoelectric Energy Harvesting from Aeroelastic Vibrations: A Lumped-Parameter Piezoaeroelastic Energy Harvester Model for Harmonic Response, Experimental Validations of the Lumped-Parameter Model at the Flutter Boundary, Utilization of System Nonlinearities in Piezoaeroelastic Energy Harvesting, A Distributed-Parameter Piezoaeroelastic Model for Harmonic Response: Assumed-Modes Formulation, Time-Domain and Frequency-Domain Piezoaeroelastic Formulations with Finite-Element Modelling, Theoretical Case Study for Airflow Excitation of a Cantilevered Plate. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Piezoelectric Energy Harvesting	Alper Erturk	Wiley	2011

(Group-1): 20ESE321 Solar Hydrogen Energy Systems

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Introduction: The Current Situation, The Peak Oil Theory, Forms of Energy Sources and Environmental Impact, Sustainability of an Energy System, A Hydrogen New Energy System, Scenarios for the Future, Alternatives to Hydrogen.
Hydrogen: Hydrogen as Energy Carrier, Properties, Production, Usage Degenerative Phenomena and Material Compatibility, Components: Pipes, Joints and Valves, Transport.■

Module-2

Electrolysis and Fuel Cells: Introduction, Chemical Kinetics, Thermodynamics, Electrode Kinetics, Energy and Exergy of the Cell, Electrolyser, Fuel Cell.
Solar Radiation and Photovoltaic Conversion: Solar Radiation, Photovoltaic Effect, Semiconductors and the p-n Junction, Crystalline Silicon Photovoltaic Cells, Other Cell Technologies, Conversion Losses, Changes in the I-U Curve, Photovoltaic Cells and Modules, Types of Photovoltaic Plants, Radiation on the Receiving Surface, Determination of the Operating Point. ■

Module-3

Wind Energy: Introduction, Mathematical Description of Wind, Wind Classification, Mathematical Model of the Aerogenerator, Power Control and Design, Wind Turbine Rating, Electric Energy Conversion, Calculation Example, Environmental Impact.
Other Renewable Energy Sources for Hydrogen Production: Solar Thermal Energy, Hydroelectric Energy, Tidal, Wave and Ocean Thermal Energy Conversions, Biomasses. ■

Module-4

Hydrogen Storage: Issues of Hydrogen Storage, Physical Storage, Physical-Chemical Storage, Chemical Storage.
Other Electricity Storage Technologies: Introduction, Electrochemical Storage, Ultra-capacitors, Compressed Air, Underground Pumped Water, Pumped Heat, Natural Gas Production, Flywheels, Superconducting Magnetic Energy Storage. ■

Module-5

Study and Simulation of Solar Hydrogen Energy Systems: Solar Hydrogen Energy Systems, Control Logic, Performance Analysis, Simulation with PV Conversion and Compression Storage, Simulation with PV Conversion and Activated-Carbon Storage, Simulation with Wind Energy Conversion, Compression and Activated-Carbon Storage, Notes on Exergy Analysis, Remarks on the Simulation of Solar Hydrogen Energy Systems.
Real-Life Implementations of Solar Hydrogen Energy Systems: Introduction, The first Project, The Schatz Solar Hydrogen Project, The ENEA Project, The Zollbruck Full Domestic System, The GlasHusEtt Project, The Trois Rivi`ere Plant, The SWB Industrial Plant, The HaRI Project, Results from Real-Life Implementations. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Solar Hydrogen Energy Systems Science and Technology for the Hydrogen Economy	Gabriele Zini et al	Springer	2012

(Group-1): 20ESE31 Energy Audit

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Types of Energy Audits and Energy-Audit Methodology: Definition of Energy Audit, Place of Audit, Energy – Audit Methodology, Financial Analysis, Sensitivity Analysis, Project Financing Options, Energy Monitoring and Training.
Survey Instrumentation: Electrical Measurement, Thermal Measurement, Light Measurement, Speed Measurement, Data Logger and Data – Acquisition System, Thermal Basis.
Energy Audit of Boilers: Classification of Boilers, Parts of Boiler, Efficiency of a Boiler, Role of excess Air in Boiler Efficiency, Energy Saving Methods. ■

Module-2

Energy Audit of Furnaces: Parts of a Furnace, classification of Furnaces, Energy saving Measures in Furnaces, Furnace Efficiency.
Energy Audit of a Power Plant: Indian Power Plant Scenario, Benefit of Audit, Types of Power Plants, Energy Audit of Power Plant.
Energy Audit of Steam-Distribution Systems: Steam as Heating Fluid, Steam Basics, Requirement of Steam, Pressure, Piping, Losses in Steam Distribution Systems, Energy Conservation Methods. ■

Module-3

Compressed Air System: Classification of Compressors, Types of Compressors, Compressed Air – System Layout, Energy – Saving Potential in a Compressed – Air System.
Energy Audit of HVAC Systems: Introduction to HVAC, Components of Air – Conditioning System, Types of Air – Conditioning Systems, Human Comfort Zone and Psychrometry, Vapour – Compression Refrigeration Cycle, Energy Use Indices, Impact of Refrigerants on Environment and Global Warming, Energy – Saving Measures in HVAC, Star Rating and Labelling by BEE.
Electrical-Load Management: Electrical Basics, Electrical Load Management, Variable- Frequency Drives, Harmonics and its Effects, Electricity Tariff, Power Factor, Transmission and Distribution Losses. ■

Module-4

Energy Audit of Motors: Classification of Motors, Parameters related to Motors, Efficiency of a Motor, Energy Conservation in Motors, BEE Star Rating and Labelling.
Energy Audit of Pumps, Blowers and Cooling Towers: Pumps, Fans and Blowers, Cooling Towers. ■

Module-5

Energy Audit of Lighting Systems: Fundamentals of Lighting, Different Lighting Systems, Ballasts, Fixtures (Luminaries), Reflectors, Lenses and Louvres, Lighting Control Systems, Lighting System Audit, Energy Saving Opportunities.
Energy Audit Applied to Buildings: Energy – Saving Measures in New Buildings, Water Audit, Method of Audit, General Energy – Savings Tips Applicable to New as well as Existing Buildings. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Handbook on Energy Audit	Sonal Desai	Mc Graw Hill	2015

(Group-1): 20EMS12 Analysis of Linear Systems

Exam Hours: 3 hours | **Exam Marks (Maximum):100**

Module-1

State space Representation of Continuous Time Systems: Introduction, concepts of state, consistency conditions, State space representation using physical variables, phase variables, canonical variables. Eigen values, Eigen vectors, state equations for dynamic systems, Non-uniqueness of state model, state diagrams- state diagrams for continuous time state models. ■

Module-2

State Space Representation of Discrete Time Systems: Digital control system, quantizing and quantization error, Data acquisition and conversion, Impulse sampling and data hold, pulse transfer function, State space representation of discrete time systems, State diagrams - state diagrams for discrete time state models. ■

Module-3

Solution of State Equations: Introduction, Existence and Uniqueness of solution to continuous time state equations, Solution of Linear time invariant continuous time state equations – Evaluation of matrix exponential, series evaluation, Evaluation using symmetry transformation, Evaluation using Cayley- Hamilton technique, Evaluation using Inverse Laplace transformation. Solution of Discrete time state equations – Z transform approach, Pulse transfer function matrix, Discretization of continuous time state space equations. ■

Module-4

Controllability and Observability of Systems: Introduction, General Concept of Controllability, General Concept of Observability, Controllability Tests For Continuous Time Systems – Time Invariant Case, Observability Tests For Continuous Time Systems – Time Invariant Case, Controllability and Observability of Discrete Time Systems – Time Invariant Case
Controllability and Observability of State Model in Jordan Canonical Form. Loss of Controllability and Observability due to Sampling. ■

Module-5

Model Control: Introduction, Controllable and Observable Companion Forms – Single Input /Single Output Systems, Effect of State feedback on Controllability and Observability, Pole Placement by State Feedback- Single Input Systems, Stabilizability, Full Oder Observer, Reduced Order Observer, Deadbeat Observer. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

1	Modern Control System Theory	M Gopal	New Age International	2012 Reprint
2	Discrete Time Control Systems	Ogata K	PHI	2nd Edition, 2016

(Group-1): 20ECD242 Process Control and Instrumentation	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Introduction to Process Control: Introduction, Process Control, Definition of the Elements in a Control Loop, Instrumentation and Sensors, Control System Evaluation, Analog and Digital Data, Process Facility Considerations.
Units and Standards: Introduction, Basic Units, Units Derived from Base Units, Standard Prefixes, Standards.
Basic Electrical Components: Introduction, Circuits with R, L, and C, RC Filters, Bridge Circuits.
Analog Electronics: Introduction, Analog Circuits, Types of Amplifiers, Amplifier Applications. ■

Module-2

Digital Electronics: Introduction, Digital Building Blocks, Converters, Data Acquisition Devices,Basic Processor.
Microelectromechanical Devices and Smart Sensors: Introduction, Basic Sensors, Piezoelectric Devices, Microelectromechanical Devices, Smart Sensors Introduction.
Pressure: Introduction, Pressure Measurement, Measuring Instruments, Application Considerations.
Level: Introduction, Level Measurement, Application Considerations. ■

Module-3

Flow: Introduction, Fluid Flow, Flow Measuring Instruments, Application Considerations.
Temperature and Heat: Introduction, Temperature and Heat, Temperature Measuring Devices, Application Considerations.
Position, Force, and Light: Introduction, Position and Motion Sensing, Force, Torque, and Load Cells, Light. ■

Module-4

4Humidity and Other Sensors: Humidity, Density and Specific Gravity, Viscosity, Sound, pH Measurements, Smoke and Chemical Sensors.
Regulators, Valves, and Motors: Introduction, Pressure Controllers, Flow Control Valves, Power Control, Motors, Application Considerations.
Programmable Logic Controllers: Introduction, Programmable Controller System, Controller Operation, Input/output Modules, Ladder Diagrams. ■

Module-5

Signal Conditioning and Transmission: Introduction, General Sensor Conditioning, Conditioning Considerations for Specific Types of Devices, Digital Conditioning, Pneumatic Transmission, Analog Transmission, Digital Transmission, Wireless Transmission.
Process Control: Introduction, Sequential Control, Discontinuous Control, Continuous Control, Process Control Tuning, Implementation of Control Loops.
Documentation and P&ID: Introduction, Alarm and Trip Systems, PLC Documentation, Pipe and Instrumentation Symbols, P&ID Drawings. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.

Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Introduction to Instrumentation, Sensors, and Process Control	William C. Dunn	Artech House	2006

(Group-1): 20EMS15 Industrial Control Technology – 1	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Industrial Control Systems: Embedded Control Systems, Real-Time Control Systems, Distributed Control System.
Industrial Control Engineering: Industrial Process Controls, Industrial Motion Controls, Industrial Production Automation. ■

Module-2

Sensors and Actuators: Industrial Optical Sensors, Industrial Physical Sensors, Industrial Measurement Sensors, Industrial Actuators. ■

Module-3

Transducers and Valves: Industrial Switches, Industrial Transducers, Industrial Valves. ■

Module-4

Microprocessors: Single-Core Microprocessor Units, Multicore Microprocessor Units.■

Module-5

Programmable-Logic and Application-Specific Integrated Circuits (PLASIC): Fabrication Technologies and Design Issues, Field-Programmable-Logic Devices, Peripheral Programmable-Logic Devices. ■

Graduate Attributes (As per NBA):
Engineering Knowledge, Problem Analysis.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Advanced Industrial Control Technology	Peng Zhang	Elsevier	2010

(Group - 1): 20EMS21 Optimal Control Theory

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Introduction: Problem Formulation, State Variable Representation of a System.
The Performance Measure: Performance Measure for Optimal Control Problems, Selecting a Performance Measure, Selection of a Performance Measure.
Dynamic Programming: The optimal Control Law, the Principle of Optimality, Application of the principle of Optimality to Decision- Making, Dynamic Programming applied to a Routing Problem, An Optimal Control System, Interpolation. ■

Module-2

Dynamic Programming (continued): A Recurrence Relation of Dynamic Programming, Computational Procedure for Solving Control Problems, Characteristics of Dynamic Programming Solution, Analytical Results – Linear Regulator Problems, The Hamilton- Jacobi-Bellman Equation, Continuous Linear Regulator Problem, The Hamilton- Jacobi-Bellman Equation – Some Observations.
The Calculus Of Variations: Fundamental Concepts, Functions of a Single Function. ■

Module-3

The Calculus of Variations (continued): Functionals involving several independent Functions, Piecewise – smooth Externals, Constrained Extrema.
The Variational Approach to Optimal Control Problems: Necessary Conditions for Optimal Control. ■

Module-4

The Variational Approach to Optimal Control Problems (continued): Linear regulator problem, Pontryagin's Minimum Principle and state Inequality Constraints, Minimum –Time problems. ■

Module-5

The Variational Approach to Optimal Control Problems (continued): Minimum Control-Effort Problems, Singular Intervals in Optimal Control Problems. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Optimal Control Theory An Introduction	Donal E Kirk	Dover Publication	2004

Visvesvaraya Technological University, Belagavi.
Ph.D Coursework Courses – 2020 in Electrical and Electronics Engineering

Ph.D Coursework Courses under Group 2

(Group - 2): 20EPS15 Power Electronic Converters	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**
Module-1	
PWM DC/DC Converters: Forward Converters - Analysis of the Basic Circuit, Galvanically Isolated Forward Converter, Boost Converter - Analysis of the Basic Scheme, Variation of the Output Voltage, Boundary Between the Continuous and the Discontinuous Mode , Discontinuous Mode Power Losses, Indirect Converter - Boundary Between the Continuous and the Discontinuous Mode, Discontinuous Mode, Indirect Converter with Galvanic Separation, Push – Pull (Symmetric) Converters - Analysis of Idealized Circuit in Continuous Mode, Output Characteristics, Selection of Components, DC Premagnetization of the Core, Half-Bridge Converter, Bridge Converter, Hamilton Circuit, Ćuk Converters - Elimination of the Current Ripple, Ćuk Converters with Galvanic Isolation. ■	
Module-2	
Control Modules: Basic Principles and Characteristics of PWM Control Modules - Circuit Analysis, Simple PWM, Voltage-Controlled PWM, Current-Controlled PWM- Compensated PWM, IC Control Modules - Control Module TL494, Control Module SG1524/2524/3524, Control Module TDA 1060. **DC/AC Converters – Inverters:** Single-Phase Voltage Inverters - Pulse-Controlled Output Voltage, Pulse-Width Modulated Inverters - Unipolar PWM, Three-Phase Inverters-Over modulation ($m_a > 1$), Asynchronous PWM, Space Vector Modulation - Space Vector Modulation: Basic Principles, Application of Space Vector Modulation Technique, Direct and Inverse Sequencing, Real Drive Influence. ■	
Module-3	
AC/DC Converters – Rectifiers: Half-Wave Single-Phase Rectifiers , Full-Wave Rectifiers - Commutation of Current, Output Filters - Capacitive Filter, L Filter,Voltage Doublers, Three-Phase Rectifiers, Phase Controlled Rectifiers - Full-Wave Thyristor Rectifiers, Three-Phase Thyristor Bridge Rectifiers, Twelve-Pulse Rectifiers, Rectifiers with Circuit for Power Factor Correction, Active Rectifier - Active Rectifier with Hysteresis Current Controller, PWM Rectifiers - Advanced Control Techniques of PWM Rectifiers , PWM Rectifier with Current Output, PWM Rectifiers in Active Filters, Some Topologies of PWM Rectifiers, Applications of PWM Rectifiers.■	
Module-4	
Resonant Converters: Resonant Circuits - Resonant Converters of Class D, Series Resonant Converters, Parallel Resonant Converters, Series – Parallel Resonant Converter, Series Resonant Converters Based on GTO Thyristors, Class E Resonant Converters, DC/DC Converters Based on Resonant Switches - ZCS Quasi-resonant Converters, ZVS Quasi-resonant Converters, Multiresonant Converters, ZVS Resonant DC/AC Converters, Soft Switching PWM DC/DC Converters -Phase Shift Bridge Converters, Resonant Transitions PWM Converters, Control Circuits of Resonant Converters - Integrated Circuit Family UCx861-8, Integrated Circuits for Control of Soft, Switching PWM Converters.■	
Module-5	
AC/AC Converters: Single-Phase AC/AC Voltage Converters - Time Proportional Control Three-Phase Converters, Frequency Converters, Direct Frequency Converters, Introduction to AC/AC Matrix Converters - Basic Characteristics, Bidirectional Switches, Realization of Input Filter, Current Commutation, Protection of Matrix Converter, Application of Matrix Converter. **Introduction to Multilevel Converters:** Basic Characteristics -Multilevel DC/DC Converters, Time Interval: $nT < t < nT + DT$, $n = 0, 1, 2$,Time Interval: $nT + DT < t < (n + 1)T$, Multilevel Inverters - Cascaded H-Bridge Inverters, Diode-Clamped Multilevel Inverters, Flying Capacitor Multilevel Inverter, Other Multilevel Inverter Topologies, Control of Multilevel Inverters - Multilevel SPWM, Space Vector Modulation, Space Vector Control, Selective Harmonic Elimination. ■	
Question paper pattern: • The question paper will have ten questions. • Each full question is for 20 marks. • There will be 2 full questions (with a maximum of four sub questions in one full question) from each module. • Each full question with sub questions will cover the contents under a module. • Students will have to answer 5 full questions, selecting one full question from each module. ■	

Text/Reference Books				
1	Power Electronics Converters and Regulators	Branko L. Doki ć Branko Blanu š a	Springer (International Publishing, Switzerland)	3rd Edition, 2015
2	Power Electronics Converters, Applications, and Design	Ned Mohan at el	Wiley	3rd Edition,2014

(Group - 2): 20EPS322 Power System Reliability

Exam Hours: 3 hours | **Exam Marks(Maximum):100**

Module-1

Introduction: Background, Changing scenario, Probabilistic reliability criteria, Statistical and probabilistic measures, Absolute and relative measures, Methods of assessment, Concepts of adequacy and security, System analysis.
Generating capacity---basic probability methods: Introduction, The generation system model, Loss of load indices, Equiva1ent forced outage rate, Capacity expansion analysis, Scheduled outages, Evaluation methods on period bases, Load forecast uncertainty, Forced outage rate uncertainty, Loss of energy indices, Practical system studies, Problems. ■

Module-2

Generating capacity-frequency and duration method: Introduction, The generation model, System risk indices, Practical system studies, Problems.
Interconnected systems: Introduction, Probability array method in two interconnected systems, Equivalent assisting unit approach to two interconnected systems, Factors affecting the emergency assistance available through the interconnections, Variable reserve versus maximum peak load reserve, Reliability evaluation in three interconnected systems, Multi-connected systems, Frequency and duration approach, Problems. ■

Module-3

Operating reserve: General concepts, PJM method, Extensions to PJM method, Modified PJM method, Postponable outages, Security function approach, Response risk, Interconnected systems, Problems.
Composite generation and transmission systems: Introduction, Radial configurations, Conditional probability approach, Network configurations, State selection, System and load point indices, Application to practica1 systems, Data requirements for composite system reliability evaluation, Problems. ■

Module-4

Distribution systems--basic techniques and radial networks: Introduction, Evaluation techniques, Additional interruption indices, Application to radial systems, Effect of lateral distributor protection, Effect of disconnects, Effect of protection failures, Effect of transferring loads, Probability distributions of reliability indices, Problems.
Distribution systems--parallel and meshed networks: Introduction, Basic evaluation techniques, Inc1usion busbar failures, Inc1usion of scheduled maintenance, Temporary and transient failures, Inclusion of weather effects, Common mode failures, Common mode failures and weather effects, Inclusion of breaker failures, Problems. ■

Module-5

Substations and switching stations: Introduction, Effect of short circuits and breaker operation, Operating and failure states of system components, Open and short circuit failures, Active and passive failures, Malfunction of normally closed breakers, Numerical analysis of typical substation, Malfunction of alternative supplies, Problems.
Plant and station availability: Generating plant availability, Derated states and auxiliary systems, Allocation and effect of spares, Protection systems, HVDC systems, Problems. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Reliability Evaluation of Power Systems	Roy Billinton et al	Elsevier	2nd Edition, 2015

(Group - 2): 20EPS254 Wind Energy Systems

Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Wind Energy Systems: Introduction, Overview of Wind Energy Conversion Systems, Wind Turbine Technology, Wind Energy Conversion System Configurations, Grid Code.
Fundamentals of Wind Energy Conversion System Control: Introduction, Wind Turbine Components, Wind Turbine Aerodynamics, Maximum Power Point Tracking (MPPT) Control. ■

Module-2

Wind Generators and Modelling: Introduction, Reference Frame Transformation, Induction Generator Models, Synchronous Generators.
Power Converters in Wind Energy Conversion Systems: Introduction, AC Voltage Controllers (Soft Starters), Interleaved Boost Converters, Two-Level Voltage-Source Converters.■

Module-3

Power Converters in Wind Energy Conversion Systems (continued): Three-Level Neutral Point Clamped Converters, PWM Current Source Converters, Control of Grid-Connected Inverter.
Wind Energy System Configurations: Introduction, Fixed-Speed WECS, Variable-Speed Induction Generator WECS, Variable-Speed Synchronous Generator WECS. ■

Module-4

Fixed**-Speed Induction Generator WECS:** Introduction, Configuration of Fixed-Speed Wind Energy Systems, Operation Principle, Grid Connection with Soft Starter, Reactive Power Compensation.
Variable-Speed Wind Energy Systems with Squirrel Cage Induction Generators: Introduction,
Direct Field Oriented Control, Indirect Field Oriented Control, Direct Torque Control, Control of Current Source Converter Interfaced WECS.■

Module-5

Doubly Fed Induction Generator Based WECS: Introduction, Super-and Subsynchronous Operation of DFIG, Unity Power Factor Operation of DFIG, Leading and Lagging Power Factor Operation, Stator Voltage Oriented Control of DFIG WECS, DFIG WECS Start-Up and Experiments. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Power Conversion and Control of Wind Energy Systems	BinWu et al	Wiley	2011

(Group - 2): 20EPS244 High-Power Battery Technologies

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Current Status of Rechargeable Batteries and Fuel Cells: Rechargeable Batteries, Fundamental Aspects of a Rechargeable Battery, Rechargeable Batteries Irrespective of Power Capability, Rechargeable Batteries for Commercial and Military Applications, Batteries for Low-Power Applications, Fuel Cells.

Batteries for Aerospace and Communications Satellites: Introduction, On-board Electrical Power System, Battery Power Requirements and Associated Critical Components, Cost-Effective Design Criterion for Battery-Type Power Systems for Spacecraft, Spacecraft Power System Reliability, Ideal Batteries for Aerospace and Communications Satellites, Performance Capabilities and Battery Power Requirements for the Latest Commercial and Military Satellite Systems, Military Satellites for Communications, Surveillance, Reconnaissance, and Target Tracking, Batteries Best Suited to Power Satellite Communications Satellites. ■

Module-2

Fuel Cell Technology: Introduction, Performance Capabilities of Fuel Cells Based on Electrolytes, Low-Temperature Fuel Cells Using Various Electrolytes, Fuel Cells Using a Combination of Fuels, Fuel Cell Designs for Multiple Applications, Ion-Exchange Membrane Fuel Cells, Potential Applications of Fuel Cells, Fuel Cells for Aircraft Applications, Fuel Cells for Commercial, Military, and Space Applications, Fuel Cells Capable of Operating in Ultra-High-Temperature Environments, Fuel Cell Requirements for Electric Power Plant Applications. ■

Module-3

Batteries for Electric and Hybrid Vehicles: Introduction, Chronological Development History of Early Electric Vehicles and Their Performance Parameters, Electric and Hybrid Electric Vehicles Developed Earlier by Various Companies and Their Performance Specifications, Development History of the Latest Electric and Hybrid Electric, Vehicle Types and Their Performance Capabilities and Limitations, Performance Requirements of Various Rechargeable Batteries, Materials for Rechargeable Batteries, Rechargeable Batteries, Critical Role of Rare Earth Materials in the Development of EVs and HEVs. ■

Module-4

Low Power Rechargeable Batteries for Commercial, Space, and Medical Applications: Introduction, Low-Power Battery Configurations, Batteries for Miniaturized Electronic System Applications, Batteries for Medical Applications, Selection Criteria for Primary and Secondary (Rechargeable) Batteries for Specific Applications. ■

Module-5

Rechargeable Batteries for Military Applications: Introduction, Potential Battery Types for Various Military System Applications, Low-Power Batteries for Various Applications, High-Power Lithium and Thermal Batteries for Military Applications, High-Power Rechargeable Batteries for Underwater Vehicles, High-Power Battery Systems Capable of Providing Electrical Energy in Case of Commercial Power Plant Shutdown over a Long Duration, Batteries Best Suited for Drones and Unmanned Air Vehicles. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Next-Generation Batteries and Fuel Cells for Commercial, Military, and Space Applications	A.R. JHA	CRC Press	2012

(Group -2): 20EPS334 Cybersecurity in the Electricity Sector	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**
odule-1	
Introduction: Transformation, Dependence on the ICT, 8Cybersecurity, Priority Critical Infrastructure. **State of Cybersecurity in the Electricity Sector:** Introduction, Vulnerabilities, Threats, Challenges, Initiatives, Future Directions. ■	
Module-2	
Cybersecurity Standards Applicable to the Electricity Sector: Introduction, Literature Search, Literature Analysis, Standards' Selection and Evaluation Criteria, Results, Most Relevant Standards, Standards' Limitations, Standards' Implementation and Awareness. ■	
Module-3	
A Systematic Approach to Cybersecurity Management: Introduction, Cybersecurity Management Approaches in Standards, The Systematic Approach to Cybersecurity Management in the Electricity Sector. ■	
Module-4	
Cost of Cybersecurity Management: Introduction, Economic Studies, Organisation Management Studies, Cost-Benefit Analysis, Cost Calculators, Costing Metrics, CAsPeA. **Cybersecurity Assessment:** Introduction, Security Assessment Methods for the Electricity Sector, Cybersecurity Test beds for Power Systems, JRC Cybersecurity Assessment Method, Laboratory Infrastructure, MAlSim. ■	
Module-5	
Cybersecurity Controls: Introduction, Standard Technical Solutions, Information Sharing Platform on Cybersecurity Incidents for the Energy Sector, Situation Awareness Network. ■	
Question paper pattern: The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60. • The question paper will have ten full questions carrying equal marks. • Each full question is for 20 marks. • There will be two full questions (with a maximum of four sub questions) from each module. • Each full question will have sub question covering all the topics under a module. • The students will have to answer five full questions, selecting one full question from each module. ■	
Textbook	
1. Cybersecurity in the Electricity Sector, Rafal Leszczyna, Springer, 2019	

(Group - 2): 20EPE14 Modelling and Design of Controllers

Exam Hours: 3 hours | **Exam Marks(Maximum):100**

Module-1

Computer Simulation of Power Electronic Converters and Systems: Introduction, Challenges in Computer Simulation, Simulation Process, Mechanics of Simulation, Solution Techniques for Time-Domain Analysis, Widely Used, Circuit-Oriented Simulators, Equation Solvers.

Modelling of Systems: Input-Output relations, Differential Equations and Linearization, State Space Representation, Transfer Function Representation, Block Diagrams, Lagrange method, Circuit Averaging, Bond Graphs, Space Vector Modelling. ■

Module-2

Control System Essentials: Representation of system in digital Domain, The Z – Transform, Digital Filter, Mapping between s – plane and z – plane, Effect of Sampling, Continuous to Discrete Domain Conversion, Control System Basics, Control Principles, State - Space Method. ■

Module-3

Digital Controller Design: Controller Design Techniques, Bode Diagram Method, PID Controller, Root Locus Method, State Space Method, Full State Feedback, Regulator Design by Pole Placement, Estimation Design, Tracker: Controller Design. ■

Module-4

Digital Controller Design (continued): Controlling Voltage, Controlling Current, Control of Induction motor, Output Feedback, Induction motor Control with Output Feedback.

Optimal and Robust Controller Design: Least Squares Principle, Quadratic Forms, Minimum Energy Principle, Least Square Solution, Weighted Least Squares, Recursive Least Squares, Optimal Control: Linear Quadratic, Induction motor example, Robust Controller Design. ■

Module-5

Discrete Computation Essentials: Numeric Formats, Tracking the Base Point in the Fixed Point System, Normalization And Scaling, Arithmetic Algorithms. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

1	Power Electronics Converters, Applications, and Design	Ned Mohan, Tore M. Undeland, William P. Robbins	Wiley	3rd Edition,2014
2	Power Electronics Essentials and Applications	L.Umanand	Wiley	1st Edition,2014

(Group - 2): 20EPE242 Uninterruptible Power Supply

Exam Hours: 3 hours | **Exam Marks(Maximum):100**

Module-1

Uninterruptible Power Supplies: Classification, Batteries for UPS Applications, Flywheels for UPS Applications, Comparative Analysis of Flywheels and Electrochemical Batteries, Applications of UPS Systems, Parallel Operation, Performance Evaluation of UPS Systems, Power Factor Correction in UPS Systems, Control of UPS Systems, Converters for UPS Systems, Battery Charger/Discharger. ■

Module-2

Active Filters: Harmonic Definition, Harmonic Sources in Electrical Systems, Effects of Harmonics, Harmonic Mitigation Methods, Classification of Active Filters, Active Filters for DC/DC Converters, Modelling and Analysis, Control Strategies, Stability Assessment. ■

Module-3

Unified Power Quality Conditioners: Series–Parallel Configuration, Current Control, Voltage Control, Power Flow and Characteristic Power.

Reduced-Parts Uninterruptible Power Supplies: Concept of Reduced-Parts Converters Applied to Single-Phase On-Line UPS Systems, New On-Line UPS Systems Based on Half-Bridge Converters. ■

Module-4

New On-Line UPS Systems Based on a Novel AC/DC Rectifier: New Three-Phase On-Line UPS System with Reduced Number of Switches, New Single-Phase to Three-Phase Hybrid Line-Interactive/On-Line UPS System. ■

Module-5

Reduced-Parts Active Filters: Reduced-Parts Single-Phase and Three-Phase Active Filters, Reduced-Parts Single-Phase Unified Power Quality Conditioners, Reduced-Parts Single-Phase Series–Parallel Configurations, Reduced-Parts Three-Phase Series–Parallel Configurations.

Modelling, Analysis, and Digital Control: Systems Modelling Using the Generalized State Space Averaging Method, Digital Control. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text/Reference Books

1	Uninterruptible Power Supplies and Active Filters	Ali Emadi et al	CRC Press	2005
2	Uninterruptible Power Supplies and Standby Power Systems	Alexander C King, William Knight	McGraw-Hill	2003

(Group - 2): 20EPE243 Hybrid Electric Vehicles

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Introduction: Sustainable Transportation, A Brief History of HEVs, Why EVs Emerged and Failed, Architectures of HEVs, Interdisciplinary Nature of HEVs, State of the Art of HEVs, Challenges and Key Technology of HEVs.
Hybridization of the Automobile: Vehicle Basics, Basics of the EV, Basics of the HEV, Basics of Plug-In Hybrid Electric Vehicle (PHEV), Basics of Fuel Cell Vehicles (FCVs).
HEV Fundamentals: Introduction, Vehicle Model, Vehicle Performance, EV Powertrain Component Sizing, Series Hybrid Vehicle, Parallel Hybrid Vehicle, Wheel Slip Dynamics. ■

Module-2

Plug-in Hybrid Electric Vehicles: Introduction to PHEVs, PHEV Architectures, Equivalent Electric Range of Blended PHEVs, Fuel Economy of PHEVs, Power Management of PHEVs, PHEV Design and Component Sizing, Component Sizing of EREVs, Component Sizing of Blended PHEVs, HEV to PHEV Conversions, Other Topics on PHEVs, Vehicle-to-Grid Technology.
Power Electronics in HEVs: Introduction, Principle of Power Electronics, Rectifiers Used in HEVs, Buck Converter Used in HEVs, Non-isolated Bidirectional DC–DC Converter, Voltage Source Inverter, Current Source Inverter, Isolated Bidirectional DC–DC Converter, PWM Rectifier in HEVs, EV and PHEV Battery Chargers, Modelling and Simulation of HEV Power Electronics, Emerging Power Electronics Devices, Circuit Packaging, Thermal Management of HEV Power Electronics. ■

Module-3

Electric Machines and Drives in HEVs: Introduction, Induction Motor Drives, Permanent Magnet Motor Drives, Switched Reluctance Motors, Doubly Salient Permanent Magnet Machines, Design and Sizing of Traction Motors, Thermal Analysis and Modelling of Traction Motors. ■

Module-4

Batteries, Ultracapacitors, Fuel Cells, and Controls: Introduction, Battery Characterization, Comparison of Different Energy Storage Technologies for HEVs, Modelling Based on Equivalent Electric Circuits, Battery Charging Control, Charge Management of Storage Devices, Flywheel Energy Storage System, Hydraulic Energy Storage System, Fuel Cells and Hybrid Fuel Cell Energy Storage System. ■

Module-5

Modelling and Simulation of Electric and Hybrid Vehicles: Introduction, Fundamentals of Vehicle System Modelling, HEV Modelling Using ADVISOR, HEV Modelling Using PSAT, Physics-Based Modelling, Bond Graph and Other Modelling Techniques, Consideration of Numerical Integration Methods, Conclusion.
HEV Component Sizing and Design Optimization: Introduction, Global Optimization Algorithms for HEV Design, Model-in-the-Loop Design Optimization Process, Parallel HEV Design Optimization Example, Series HEV Design Optimization Example, Conclusion.
Vehicular Power Control Strategy and Energy Management: A Generic Framework, Definition, and Needs, Methodology to Implement, Benefits of Energy Management. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Hybrid Electric Vehicles principles and Applications with Practical Perspectives	Chris Mi,M. Abul Masrur,David Wenzhong Gao	Wiley	2011

(Group - 2): 20ESE13 Energy Production, Conversion and Conservation

Exam Hours: 3 hours | **Exam Marks(Maximum):100**

Module-1

Basic Definitions: System, Property and Variables, Dimensions and Units, Measures of Amounts and Fractions, Force, Temperature, Pressure, Volume, State, Process, Problems.

Energy and Energy Types: Energy, Energy Types, Non Renewable Energy Sources, Heating Value of Fuel, Renewable Energy Resources, Hydrogen, Electric Energy, Magnetic Energy, Chemical Energy, Energy and Global Warming, Tackling the Global Warming. ■

Module-2

Mechanical Energy and Electrical Energy: Mechanical Energy, Kinetic Energy,
Potential Energy, Pressure Energy, Surface Energy, Sound Energy, Mechanical Work,Electric Energy, Other Forms of Work.

Internal Energy and Enthalpy: Internal Energy, Enthalpy, Heat, Effect of Temperature on the Heat of Reaction, Standard Enthalpy Changes, Adiabatic Flame Temperature, Air Pollution from Combustion Processes, Heat of Mixing, Heat Measurements by Calorimeter, Psychrometric Diagram, Heat Transfer, Entropy, Energy, Fluid-Flow Work. ■

Module-3

Energy Balances: Balance Equations, Mass Balance, Energy Balance, Entropy Balance, Energy Balance, Fluid-Flow Processes, Energy Balance in a Cyclic Process.

Energy Production: Energy Production, Electric Power Production, Transmission of Energy, Power Producing Engine Cycles, Improving the Power Production in Steam Power Plants, Geothermal Power Plants, Cogeneration, Nuclear Power Plants, Hydropower Plants, Wind Power Plants, Solar Power Plants, Hydrogen Production, Fuel Cells, Biomass and Bioenergy Production, Other Energy Production Opportunities, Levelized Energy Cost, Thermodynamic Cost, Ecological Cost. ■

Module-4

Energy Conversion: Energy Conversion, Series of Energy Conversions, Conversion of Chemical Energy of Fuel to Heat, Thermal Efficiency of Energy Conversions, Ideal Fluid-Flow Energy Conversions, Lost Work, Efficiency of Mechanical Conversions, Conversion of Thermal Energy by Heat Engines, Improving Efficiency of Heat Engines, Hydroelectricity, Wind Electricity, Geothermal Electricity, Ocean Thermal Energy Conversion, Thermoelectric Effect, Efficiency of Heat Pumps and Refrigerators, Efficiency of Fuel Cells, Energy Conversions in Biological Systems. ■

Module-5

Energy Storage: Energy Storage and Regulation, Types of Energy Storage, Thermal Energy Storage, Electric Energy Storage, Chemical Energy Storage, Mechanical Energy Storage.

Energy Conservation: Energy Conservation and Recovery, Conservation of Energy in Industrial Processes, Energy Conservation in Home Heating and Cooling. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Energy Production, Conversion, Storage, Conservation, and Coupling.	Yasar Demirel	Springer,	2012

(Group - 2): 20ESE242 Photovoltaics

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Properties of Solar Radiation: Glossary of Key PV Terms, Sun and Earth, Extraterrestrial Radiation, Radiation on the Horizontal Plane of the Earth's Surface, Simple Method for Calculating Solar Radiation on Inclined Surfaces, Radiation Calculation on Inclined Planes with Three-Component Model, Approximate Annual Energy Yield for Grid-Connected PV Systems, Composition of Solar Radiation, Solar Radiation Measurement. ■

Module-2

Solar Cells: Their Design Engineering and Operating Principles, The Internal Photoelectric Effect in Semiconductors, A Brief Account of Semiconductor Theory, The Solar Cell: A Specialized Semiconductor Diode with a Large Barrier Layer that is Exposed to Light, Solar Cell Efficiency, The Most Important Types of Solar Cells and the Attendant Manufacturing Methods, Bifacial Solar Cells, Examples. ■

Module-3

Solar Modules and Solar Generators: Solar Modules, Potential Solar Cell Wiring Problems, Interconnection of Solar Modules and Solar Generators, Solar Generator Power Loss Resulting from Partial Shading and Mismatch Loss - Power Loss Induced by Module Shading, Mismatch Loss Attributable to Manufacturing Tolerances, Mismatch Loss Attributable to String Inhomogeneity, Examples on the above topics.■

Module-4

PV Energy Systems: Stand-alone PV Systems, Grid-Connected Systems -Grid-Connected Operation, Design Engineering and Operating Principles of PV System Inverters. ■

PV Energy Systems (continued): Standards and Regulations for Grid-Connected Inverters, Avoidance of Islanding and Stand-alone Operation in Grid Inverters, Operating Performance and Characteristics of PV Grid Inverters - Conversion Efficiency, MPP Tracking Efficiency and MPP. ■

Module-5

PV Energy Systems (continued): Control Characteristics, Overall Inverter Efficiency, Dynamic MPP Tracking Test - Simple Dynamic MPP Tracking Test Using Quasi-square Test Patterns. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Photovoltaics System Design and Practice	Heinrich Ha¨berlin	Wiley	2012

(Group - 2): 20ESE15 Power System Operation

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Power System Operation: Overview, Operator, Process, Technology, Power System Operation Criteria.
Power System Monitoring: Operator Function in Power System Monitoring, Process for Power System Monitoring, Technology for Power System Monitoring, Bad Data Identification, Observability.
Power System Scenario Analysis: Operator Function in Power System Scenario Analysis, Process for Power System Scenario Analysis, Technology for Power System Control. ■

Module-2

Power System Posturing: Static Security: Operator's Question on Power System Posturing: Static Security, Process for Power System Posturing: Static Security, Technology for Power System Posturing: Static Security.
Power System Posturing: Angular Stability: Operator's Question on Power System Posturing: Angular Stability, Process for Power System Posturing: Angular Stability, Technology for Power System Posturing: Angular Stability, Implementation of Angular Stability Limits. ■

Module-3

Power System Posturing: Voltage Stability: Operator's Question on Power System Posturing: Voltage Stability, Process for Power System Posturing: Voltage Stability, Technology for Power System Posturing: Voltage Stability, Voltage Stability Limit Derivation and Implementation.
Power System Generation Load Balance: Operator's Question on Generation Load Balance, Process for Generation Load Balance, Technology for Generation Load Balance. ■

Module-4

Power System Operation Optimization: Operator's Question on Power System Operation Optimization, Process for Power System Generation Operation, Process for Generation Sufficiency, Technology for Generation Sufficiency.
System Operation Control Centers: Introduction, Modern Control Center Attributes, Control Center Redundancy Configuration, Modern Control Center Configuration, Modern Control Center Design Details. ■

Module-5

Energy Management Systems: Introduction, EMS Functionality Overview, Energy Management System Availability Criteria and Architecture.
Distribution Management System: Introduction, DMS Functionality Overview, Distribution Management System Architecture.
Evolving Power System Operation Solutions: Introduction, Evolving Operation Solutions. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Practical Power System Operation	Ebrahim Vaahedi	Wiley	2014

(Group - 2): 20ESE322 Energy Management Strategies for EV/PHEV

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Introduction: Background, HEV Fundamentals, Simulation Platform: The Advanced Vehicle, Simulator (ADVISOR) Software.

Electric and Plug-in Hybrid Electric Vehicle Drive Train Topologies: Concept of Electric, Hybrid Electric and Plug-in Hybrid Electric Vehicles, Hybrid Electric Vehicle Drive Train Topologies, Plug-in Hybrid Electric Vehicle Drive Train Topologies, All-Electric Vehicle Drive Train Topology.

EV and PHEV Energy Storage Systems: Introduction, Batteries, Electrical Modelling of Ultracapacitors, Electrical Modelling of Flywheel Energy Storage Systems, Operating Principle of a Fuel Cell. ■

Module-2

Hybrid Electric and Fuel Cell Hybrid Electric Vehicles: HEV Fundamentals and Concepts, Efficiencies of Series and Parallel HEV Drive Trains, Varied Driving Patterns and Regenerative Braking Efficiency Analysis, Regenerative Braking Efficiency Analysis, Overall Electric Drive Train Efficiency Analysis, Fuel Cell HEV: Modelling and Control, Power Electronics Interface of Fuel Cell and Traction System, Concept of Fuel Cell Plug-in HEV (FC-PHEV).

EV and PHEV Battery Technologies: 5.1 Energy Storage Issues of PHEVs and EVs. ■

Module-3

On-Board Power Electronic Battery Management: Battery Cell Voltage Equalization Problem, Introduction to Classic and Advanced Battery Cell Voltage Equalizers, Economic Significance of Battery Cell Voltage Equalization, Design and Performance of a Novel Power Electronic Cell Equalizer, Controller Design for Developed Cell Equalizer, Experimental Results. ■

Module-4

EV and PHEV Battery Charging: Grid and Renewable Energy Interface: Introduction, Charging Regimes for Batteries, Charging from Grid, Charging from Renewable Energy Sources, Power Electronics for EV and PHEV Charging, Topologies for PV Inverters, Power Converters Topology. ■

Module-5

Power Electronic Converter Topologies for EV/PHEV Charging: Grid and Photovoltaic (PV) System for EV/PHEV Charging, DC/DC Converters and DC/AC Inverters for Grid/PV Interconnection, Novel Integrated DC/AC/DC Converter for EV/PHEV Charging, High Frequency Transformer-Based Isolated Charger Topology, Component Design, Comments, Transformer-Less Charger Topology, Comments, Modelling and Simulation Results of Test System, Conclusion, High Frequency Transformer-Isolated Topology with DC-Link, Transformer-Less Topology, Efficiency,

EVs and PHEVs for Smart Grid Applications: Introduction, Vehicle-to-Grid and Grid-to-Vehicle Issues, Ancillary Services from V2G, Vehicle-to-Home and Home-to-Vehicle Concept, Interconnection Requirements, Study Case.

EV and PHEV Well-to-Wheels Efficiency Analysis: Interest in Well-to-Wheels Efficiency Analysis, Theoretical Efficiency Calculations for Advanced Vehicular Drive Trains, Simulation Setup for the Vehicle Under Study, Overall Efficiency Analysis Based on Simulation Results of the HEV and FCV Drive Train Architectures, Acceleration Performance and Well-to-Wheels Greenhouse Gas Emissions for HEV and ECV Drive Trains, Prospective Future Work. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles	Sheldon S. Williamson	Springer	2013

(Group - 2): 20EMS13 VLSI Design

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

MOS Transistor Theory: MOS Transistors, CMOS Fabrication and Layout, Long – Channel I-V Characteristics, C-V Characteristics, Non-ideal I-V Effects, DC Transfer Characteristics, Pitfalls and Fallacies.
CMOS Processing Technology: Introduction, CMOS Technologies, Layout Design Rules, CMOS Process Enhancements. ■

Module-2

Combinational Circuit Design: Introduction, Circuit Families, Circuit Pitfalls, More Circuit Families, Silicon-on-Insulator Circuit Design, Subthreshold Design, Pitfalls and Fallacies, Historical Perspective. ■

Module-3

Sequential Circuit Design: Introduction, Sequencing Static Circuits, Circuit Design of Latches and Flip-flops, Static Sequencing Element Methodology, Sequencing Dynamic Circuits, Synchronizers, Wave Pipelining, Pitfalls and Fallacies, Case study■

Module-4

Single Stage Amplifiers: Basic Concepts, Common – Source Stage, Source Follower, Common – Gate Stage, Cascode Stage, Choice of Device Models.
Differential Amplifiers: Single – Ended and Differential Operations, Basic Differential Pair, Common – Mode Response, Differential Pair with MOS Loads, Gilbert Cell.■

Module-5

Passive and Active Current Mirrors: Basic Current Mirrors, Cascode Current Mirrors, Active Current Mirrors.
Operational Amplifiers: General Considerations, One – Stage Op Amps, Two – Stage Op Amps, Gain Boosting, Comparison, Common – Mode Feedback, Input Range Limitations, Slew Rate, Power Supply Rejection, Noise in Op Amps.■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

1	CMOS VLSI Design: A Circuits and Systems Perspective	Neil H. E. Weste, David Money Harris	Pearson	4th Edition, 2015
2	Design of Analog CMOS Integrated Circuits	Behzad Razavi	Mc Graw Hill	31st Reprint, 2015

(Group-2): 20EMS31 Industrial Control Technology – 2	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**
Module-1	
Industrial Intelligent Controllers: PLC (Programmable Logic Control) Controllers, CNC (Computer Numerical Control) Controllers, FLC (Fuzzy Logic Control) Controllers. ■	
Module-2	
Industrial Process Controllers: PID (Proportional-Integral-Derivative) Controllers, BPC (Batch Process Control) Controllers, SMC (Servo Motion Control) Controllers. **Industrial Computers:** Introduction, Industrial Computer Classes and Configurations, Industrial Computer Peripherals and Accessories. ■	
Module-3	
3Industrial Control Networks: Controller Area Network (CAN), Supervisory Control and Data Acquisition (SCADA) Network, Industrial Ethernet Network, Industrial Enterprise Networks. ■	
Module-4	
Networking Devices: Hubs and Switches, Network Routers, Bridges, Gateways and Repeaters. ■	
Module-5	
Human–machine interfaces: Human–Machine Interactions, User–Machine Interfaces, Industrial Application Examples. **Data Transmission Interfaces:** Data Transmission Basics, Data Transmission I/O Devices, Data Transmission Control Devices. ■	

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Advanced Industrial Control Technology	Peng Zhang	Elsevier	2010

(Group - 2): 20EMS322 Digital System Design with FPGA

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Programmable Logic: Introduction, Electronic Circuits: Analogue and Digital, Programmable Logic versus Discrete Logic, Programmable Logic versus Processors, Types of Programmable Logic, PLD Configuration Technologies, Programmable Logic Vendors, Programmable Logic Design Methods and Tools, Technology Trends.

Design Languages: Introduction, Software Programming Languages, Hardware Description Languages, SPICE, System C ^{R}, System Verilog, Mathematical Modelling Tools. ■

Module-2

Electronic Systems Design: Introduction, Sequential Product Development Process versus Concurrent Engineering Process, Flowcharts, Block Diagrams, Gajski-Kuhn Chart, Hardware-Software Co-Design, Formal Verification, Embedded Systems and Real-Time Operating Systems, Electronic System-Level Design, Creating a Design Specification, Unified Modelling Language, Reading a Component Data Sheet, Digital Input/Output, Parallel and Serial Interfacing, System Reset, System Clock, Power Supplies, Power Management, Printed Circuit Boards and Multichip Modules, System on a Chip and System in a Package, Mechatronic Systems, Intellectual Property, CE and FCC Markings. ■

Module-3

Introduction to Digital Logic Design with VHDL: Introduction, Designing with HDLs, Design Entry Methods, Logic Synthesis. Entities, Architectures, Packages, and Configurations, A First Design, Signals versus Variables, Generics, Reserved Words, Data Types, Concurrent versus Sequential Statements, Loops and Program Control, Coding Styles for VHDL, Combinational Logic Design. ■

Module-4

Introduction to Digital Logic Design with VHDL (continued): Sequential Logic Design, Memories Unsigned versus Signed Arithmetic - Adder Example. Multiplier Example.

Testing the Design: Introduction, Integrated Circuit Testing, Printed Circuit Board Testing, Boundary Scan Testing, Software Testing. ■

Module-5

Digital-to-Analogue Conversion, and Power Electronics: Introduction, Digital-to-Analogue Conversion, Analogue-to-Digital Conversion, Power Electronics, Heat Dissipation and Heat sinks. Operational Amplifier Circuits.

System-Level Design: Introduction, Case Study-DC Motor Control. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Digital Systems Design with FPGAs and CPLDs	Ian Grout	Elsevier	2008

Ph.D Coursework Courses under Group 3

(Group -3): 20EPS323 Wide Area Measurements and their Applications

Exam Hours: 3 hours | **Exam Marks(Maximum):100**

Module-1

Phasor Measurement Techniques: Introduction, Historical overview, Phasor representation of sinusoids, Fourier series and Fourier transform, Sampled data and aliasing, Discrete Fourier transform (DFT), Leakage phenomena.
Phasor Estimation of Nominal Frequency Inputs: Phasors of nominal frequency signals, Formulas for updating phasors, Effect of signal noise and window length, Phasor estimation with fractional cycle data window, Quality of phasor estimate and transient monitor, DC offset in input signals, Non-DFT estimators.■

Module-2

Phasor Estimation at Off-Nominal Frequency Inputs: Types of frequency excursions found in power systems, DFT estimate at off-nominal frequency with a nominal frequency clock, Post-processing for off-nominal frequency estimates, Phasor estimates of pure positive sequence signals, Estimates of unbalanced input signals, Sampling clocks locked to the power frequency, Non-DFT type phasor estimators.
Frequency Estimation: Overview of frequency measurement, Frequency estimates from balanced three phase inputs, Frequency estimates from unbalanced inputs, Nonlinear frequency estimators, Other techniques for frequency measurements. ■

Module-3

Phasor Measurement Units and Phasor Data Concentrators: Introduction, A generic PMU, The global positioning system, Hierarchy for phasor measurement systems, Communication options for PMUs, Functional requirements of PMUs and PDCs.
Transient Response of Phasor Measurement Units: Introduction, Nature of transients in power systems, Transient response of instrument transformers, Transient response of filters Transient response during electromagnetic transients Transient response during power swings.■

Module-4

State Estimation: History-Operator's load flow, Weighted least square, Static state estimation, Bad data detection, State estimation with Phasors measurements, Calibration, Dynamic estimators.
Control with Phasor Feedback: Introduction, Linear optimal control, Linear optimal control applied to the nonlinear problem, Coordinated control of oscillations, Discrete event control. ■

Module-5

Protection Systems with Phasor Inputs: Introduction, Differential protection of transmission lines, Distance Relaying of multiterminal transmission lines, Adaptive protection, Control of backup relay performance, Intelligent islanding, Supervisory load shedding.
Electromechanical Wave Propagation: Introduction, The Model, Electromechanical telegrapher's equation, Continuum voltage magnitude, Effects on protection systems, Dispersion, Parameter distribution. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Synchronized Phasor Measurements and Their Applications	A.G. Phadke J.S. Thorp	Springer	2008

(Group -3): 20EPS324 Data Analytics for the Smart Grid

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Putting the Smarts in the Smart Grid: Goal, The Imperative for the Data-Driven Utility, Big Data: We'll Know It When We See It, What Are Data Analytics? Starting from Scratch, Finding Opportunity with Smart Grid Data Analytics.
Building the Foundation for Data Analytics: Chapter Goal, Perseverance Is the Most Important Tool, Building the Analytical Architecture.
Transforming Big Data for High-Value Action: Goal, The Utility as a Data Company, Algorithms, Seeing Intelligence, Assessing the Business Issues. ■

Module-2

Applying Analytical Models in the Utility: Goal, Understanding Analytical Models, Using Descriptive Models for Analytics, Using Diagnostic Models for Analytics, Predictive Analytics, Prescriptive Analytics, An Optimization Model for the Utility, Toward Situational Intelligence.
Enterprise Analytics: Goal, Moving Beyond Business Intelligence.
Operational Analytics: Goal, Aligning the Forces for Improved Decision-Making, The Opportunity for Insight, Focus on Effectiveness, Distributed Generation Operations: Managing the Mix-Up, Grid Management, Resiliency Analytics, Extracting Value from Operational Data Analytics. ■

Module-3

Customer Operations and Engagement Analytics: Goal, Increasing Customer Value, What's in It for the Customer?
Analytics for Cybersecurity: Goal, Cybersecurity in the Utility Industry, The Role of Big Data Cybersecurity Analytics.
Sourcing Data: Goal, Sourcing the Data, Working with a Variety of Data Sources. ■

Module-4

Big Data Integration, Frameworks, and Databases: Goal, This Is Going to Cost, Storage Modalities, Data Integration, The Costs of Low-Risk Approaches, Let the Data Flow, Other Big Data Databases, The Curse of Abundance.
Extracting Value: Goal, We Need Some Answers Here, Mining Data for Information and Knowledge, The Process of Data Extraction, Stream Processing, Avoid Irrational Exuberance. ■

Module-5

Envisioning the Utility: Goal, Big Data Comprehension, Why Humans Need Visualization, The Role of Human Perception, The Utility Visualized, Making Sense of It All.
A Partnership for Change: Goal, With Big Data Comes Big Responsibility, Privacy, Not Promises, Privacy Enhancement, The Utility of the Future Is a Good Partner. ■

Question paper pattern:
The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module. ■

Textbook

1. Big Data Analytics Strategies for the Smart Grid, Carol L. Stimmel, CRC Press, 2015.

(Group -3): 20EPE322 EMC in Power Electronics

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Electromagnetic Disturbances: Introduction, Classification of disturbances by frequency content, by character and transmission mode.
Conducted EMI Measurement: Introduction, EMI measuring instruments, Basic terms and conducted EMI references, Measuring the interference voltage and current, Spectrum analysers, EMI measurements for consumer applications, Measuring impulse like EMI.
EMI in Power Electronic Equipment: EMI from power semiconductors, controlled rectifier circuits, EMI calculation for semiconductor equipment. ■

Module-2

EMI Filter Elements: Measuring High Frequency Characteristics OF EMI Filter Elements, Capacitors, Choke Coils, Resistors. ■

Module-3

Noise Suppression: Noise Suppression in Relay Systems, Application of AC Switching Relays, Application of RC – Snubbers to Power Semiconductors, Shielded Transformers, Capacitor Filters, EMI Generation and Reduction at its Source, Influence of Layout and Control of Parasitics.
EMI Filter Circuit selection and measurement: Definition of EMI Filter Parameters, ENI Filter Circuits, Insertion Loss Test Methods. ■

Module-4

EMI Filter Design: EMI Filter Design for Insertion Loss, Calculation of Worst – case Insertion Loss, Design Method for Mismatched Impedance Condition, Design Method for EMI Filters with Common – Mode Choke Coils, Damped EMI Filters and Lossy Filter Elements, HF Characteristics of Noise Filter Circuit Elements, EMI Filter Layout. ■

Module-5

Testing for Susceptibility to Power Line Disturbances: Surge Voltages in AC Power Mains, EMC Tests per IEC Specifications, Other EMS Test Methods.
Reduction Techniques for internal EMI: Conductive Noise Coupling, Electromagnetic Coupling, Electromagnetic Coupling Reduction Methods, Wiring Layout Methods to Reduce EMI Coupling, PCB Design Considerations. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Electromagnetic Compatibility in Power Electronics	Laszlo Tihanyi	Newnes	1st Edition, 1995

(Group -3): 20EPE323 Multilevel Converters for Industrial Applications

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Converters: Introduction, Medium-Voltage Power Converters, Multilevel Converters, Applications.
Multilevel Topologies: Introduction, Generalized Topology with a Common DC Bus, Converters Derived from the Generalized Topology, Symmetric Topologies without a Common DC Link, Summary of Symmetric Topologies, Asymmetric Topologies. ■

Module-2

Diode-Clamped Multilevel Converter: Introduction, Converter Structure and Functional Description, Modulation of Multilevel Converters, Voltage Balance Control, Effectiveness Boundary of Voltage Balancing in DCMC Converters, Performance Results. ■

Module-3

Flying Capacitor Multilevel Converter: Introduction, Flying Capacitor Topology, Modulation Scheme for the FCMC, Dynamic Voltage Balance of the FCMC.
Cascade Asymmetric Multilevel Converter (CAMC): Introduction, General Characteristics of the CAMC, CAMC Three-Phase Inverter, Comparison of the Five-Level Topologies. ■

Module-4

Case Study 1: DSTATCOM Built with a Cascade Asymmetric Multilevel Converter: Introduction, Compensation Principles, CAMC Model, Reactive Power and Harmonics Compensation. ■

Module-5

Case Study 2: Medium-Voltage Motor Drive Built with DCMC: Introduction, Back-to-Back DCMC Converter, Unified Predictive Controller of the Back-to-Back DCMC in an IM Drive Application, Performance Evaluation. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Multilevel Converters for Industrial Applications	Sergio Alberto González, Santiago Andrés Verne, María Inés Valla	CRC Press	2014

(Group -3): 20EPE241 Converters for Solar and Wind Power Systems

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Introduction: Wind Power Development, Photovoltaic Power Development, The Grid Converter – The Key Element in Grid Integration of WT and PV Systems.

Photovoltaic Inverter Structures: Introduction, Inverter Structures Derived from H-Bridge Topology, Inverter Structures Derived from NPC Topology, Typical PV Inverter Structures, Three-Phase PV Inverters, Control Structures, Conclusions and Future Trends.

Grid Requirements for PV: Introduction, International Regulations, Response to Abnormal Grid Conditions, Power Quality, Anti-islanding Requirements. ■

Module-2

Grid Synchronization in Single-Phase Power Converters: Introduction, Grid Synchronization Techniques for Single-Phase Systems, Phase Detection Based on In-Quadrature Signals, Some PLLs Based on In-Quadrature Signal Generation, Some PLLs Based on Adaptive Filtering, The SOGI Frequency-Locked Loop. ■

Module-3

Islanding Detection: Introduction, Non-detection Zone, Overview of Islanding Detection Methods, Passive Islanding Detection Methods, Active Islanding Detection Methods.

Grid Converter Structures for Wind Turbine Systems: Introduction, WTS Power Configurations, Grid Power Converter Topologies, WTS Control.

Grid Requirements for WT Systems: Introduction, Grid Code Evolution (Germany), Frequency and Voltage Deviation under Normal Operation, Active Power Control in Normal Operation, Reactive Power Control in Normal Operation (Germany), Behaviour under Grid Disturbances (Germany), Discussion of Harmonization of Grid Codes. ■

Module-4

Grid Synchronization in Three-Phase Power Converters: Introduction, The Three-Phase Voltage Vector under Grid Faults, The Synchronous Reference Frame PLL under Unbalanced and Distorted Grid Conditions, The Decoupled Double Synchronous Reference Frame PLL (DDSRF-PLL), The Double Second-Order Generalized Integrator FLL (DSOGI-FLL).

Grid Converter Control for WTS: Introduction, Model of the Converter, AC Voltage and DC Voltage Control, Voltage Oriented Control and Direct Power Control, Stand-alone, Micro-grid, Droop Control and Grid Supporting. ■

Module-5

Control of Grid Converters under Grid Faults: Introduction, Overview of Control Techniques for Grid-Connected Converters under Unbalanced Grid Voltage Conditions, Control Structures for Unbalanced Current Injection, Power Control under Unbalanced Grid Conditions, Flexible Power Control with Current Limitation.

Grid Filter Design: Introduction, Filter Topologies, Design Considerations, Practical Examples of LCL Filters and Grid Interactions, Resonance Problem and Damping Solutions, Nonlinear Behaviour of the Filter. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Grid Converters for Photovoltaic and Wind Power Systems	Remus Teodorescu at al	Wiley	2011

(Group -3): 20EPE244 Neural and Fuzzy Logic Control of Drives	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**
Module-1	
Modern control systems design using CAD techniques: Introduction, Control systems for AC drives, Electronic design automation (EDA), Application specific integrated circuit (ASIC) basics, Field programmable gate arrays (FPGAs), ASICs for power systems and drives, Electric motors. **Electric motors:** Motors, Pulse width modulation, The space vector in electrical systems, Induction motor control. ■	
Module-2	
Elements of neural control: Neurone types, Artificial neural networks architectures, Training algorithms, Control applications of ANNs, Neural network implementation. **Neural FPGA implementation**: Neural networks design and implementation strategy, Universal programs FFANN, hardware implementation, Hardware implementation complexity analysis. ■	
Module-3	
Fuzzy logic fundamentals: Introduction, Fuzzy sets and fuzzy logic, Types of membership functions, Linguistic variables, Fuzzy logic operators, Fuzzy control systems, Fuzzy logic in power and control, Applications. **VHDL fundamentals**: Introduction, VHDL design units, Libraries, visibility and state system in VHDL, Sequential statements, Concurrent statements, Functions and procedures, Advanced features in VHDL. ■	
Module-4	
Neural current and speed control of induction motors: The induction motor equivalent circuit, The current control algorithm, The new sensorless motor control Strategy. . ■	
Module-5	
Neural current and speed control of induction motors (continued): Induction motor controller VHDLDesign, FPGA controller experimental results. ■	
Question paper pattern: The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60. • The question paper will have ten full questions carrying equal marks. • Each full question is for 20 marks. • There will be two full questions (with a maximum of four sub questions) from each module. • Each full question will have sub question covering all the topics under a module. • The students will have to answer five full questions, selecting one full question from each module. ■	
Textbook	
1. Neural and Fuzzy Logic Control of Drives and Power Systems, M.N. Cirstea, et al, Newnes, 2002.	

(Group -3): 20ECD14 AC and DC Drives – 1

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Power electronics Devices and Drives: Introduction, Power Devices and Switching, Motor Drives.
Modelling of DC Machines: Theory of Operation, Induced emf, Equivalent Circuit and Electromagnetic Torque, Electromechanical Modelling, Block Diagram and Transfer Functions, Field Excitation, Measurement of Motor Constants, Flow chart for Computation.
Phase – Controlled DC Motor Drives: Introduction, Principles of DC motor Speed Control, Phase Controlled Converters, Steady - State Analysis of the Three Phase Controlled DC Motor Drives. ■

Module-2

Phase – Controlled DC Motor Drives (continued): Two – Quadrant Three Phase Controlled DC Motor Drive, Transfer Functions of the Subsystems, Design of Controllers, Two – Quadrant DC Motor Drive with Field Weakening, Four – Quadrant DC Motor Drive, Converter Selection and Characteristics, Simulation of the One – Quadrant DC Motor Drive, Harmonics and Associated Problems, Sixth Harmonic Torque, Application Considerations, Applications, Parameter Sensitivity.
Chopper – Controlled DC Motor Drive: Introduction, Principle of operation of Chopper, Four – Quadrant Chopper Circuit, Chopper for Inversion, Chopper with Other Power Devices, Model of the Chopper, Input to the Chopper, Other Chopper Circuits, Steady – State Analysis of Chopper – Controlled DC Motor Drive, Rating of the Devices. ■

Module-3

Chopper – Controlled DC Motor Drive (continued): Pulsating Torques, Closed – Loop Operation, Dynamic Simulation, Applications.
PolyPhase Induction Machines: Introduction, Construction and Principle of Operation, Induction Motor Equivalent Circuit, Steady - State Performance Equations of the Induction Motor, Steady - State Performance, Measurement of Motor of Induction Motor, Dynamic Modelling of Induction Motor.■

Module-4

PolyPhase Induction Machines (continued): Dynamic Simulation, Small – Signal Equations of the Induction Machine, Evaluation of Control Characteristics of the Induction Machine, Space – Phasor Model, Control Principle of the Induction Motor.
Phase – Controlled Induction Motor Drives: Introduction, Stator – Voltage Conrtaol, Slip – Energy Recovery Scheme. ■

Module-5

Frequency – Controlled Induction Motor Drives: Introduction, Static Frequency Changers, Voltage Source Inverter – Driven Induction Motor. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Electric Motor Drives : Modelling, Analysis, and Control	R. Krishnan	Pearson	2016

(Group -3): 20ESE14 Energy Conversion Technologies

Exam Hours: 3 hours | **Exam Marks(Maximum):100**

Module-1

1Energy and Energy Efficiency: Energy Sources, Energy Efficiency and Contemporary Trends.
Storage and Usage of Energy: Overview, Storage of Energy as Electrochemical Energy, Storage of Energy as Electromagnetic Energy, Storage of Energy as Electrostatic Energy, Storage of Energy as Mechanical Energy, Using the Energy as Electrical Energy.
Power Electronics and Its Role in Effective Conversion of Electrical Energy: Overview, Principles of Conversion of Electrical Energy, Computer-Aided Design of Power Electronic Converters in Power Electronics. ■

Module-2

AC/DC Conversion: Basic Indicators in Respect to the Supply Network, Single-Phase and Three-Phase Uncontrolled Rectifiers, Single-Phase and Three-Phase Controlled Rectifiers, Bidirectional AC/DC Conversion, Methods to Improve Power Efficiency in AC/DC Conversion. ■

Module-3

AC/AC Conversion: Basic Indicators in Respect to the Supply Network, Single-Phase and Three-Phase AC Regulators, Methods to Improve Power Efficiency in AC/AC Conversion.
DC/DC Conversion: Basic Indicators, Conversion Without Galvanic Isolation, Conversion with Galvanic Isolation, Bidirectional DC/DC Conversion, Methods to Improve Power Efficiency in DC/DC Conversion. ■

Module-4

DC/AC Conversion: Basic Indicators, Single-Phase and Three-Phase Converters, Methods to Improve Power Efficiency in DC/AC Conversion.
Conversion of Electrical Energy in the Processes of Its Generation and Transmission:
Conversion in the Process of Electrical Generation, Static VAR Compensators, (SVC),Static Synchronous Compensator (STATCOM), Thyristor Controlled Series Compensator (TCSC), Static Synchronous Series Controller (SSSC), Unified Power Flow Controller (UPFC), Interline Power Flow Controller (IPFC), High Voltage DC Transmission. ■

Module-5

Conversion of Electrical Power from Renewable Energy Sources: Overview, Conversion of Solar Energy, Conversion of Wind Energy, Conversion of Water Energy.
Uninterruptible Power Supply Systems: Introduction, Basic Schemas and Their Indicators, Methods to Increase the Reliability, Communication between UPS Systems and Different Systems.
Other Applications of Converters and Systems of Converters: Industrial Applications, Transport Applications, Home Appliances, Elevators, Applications in Communication, Medical Applications. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Technologies for Electrical Power Conversion, Efficiency, and Distribution: Methods and Processes.	Mihail Hristov Antchev	Engineering science reference	2010

(Group -3): 20ESE243 Introduction to Nuclear Power

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

The Earth and Nuclear Power: Sources and Resources: Introduction, Earth's Internal Heat Generation, The Earth's Energy Flow, The Fission Process, Thermal Energy Resources.
How Reactors Work: Introduction, The Fission Process, Basic Components of a Nuclear Reactor, Thermal Reactors, Fast Reactors. ■

Module-2

Cooling Reactors: Introduction, General Features of a Reactor Coolant, Principles of Heat Transfer, Gaseous Coolants, Liquid Coolants, Boiling Coolants, Alternative Forms of Reactor Coolant Circuits.
Loss of Cooling: Introduction, The Electric Kettle, Pressurized-Water Reactor, Boiling-Water Reactor, CANDU Reactor, Gas-Cooled Reactors, Sodium- Cooled Fast Reactor. ■

Module-3

Loss-of-Cooling Accidents: Introduction, Incidents in light Water-Cooled Reactors, Heavy Water-Moderated Reactors, Gas-Cooled Reactors, Liquid Metal-Cooled Fas t Reactors, The International Nuclear Event Scale (INES). ■

Module-4

Postulated Severe Accidents Introduction: Introduction, Postulated Severe Accidents in Water-Cooled Reactors, Specific Phenomena relating to Severe Accidents, Severe Accidents in other Reactor Types, Fission Product Dispersion following Containment Failure.
Cooling during Fuel Removal and Processing: Introduction, Refuelling, Spent Fuel Storage and Transport, Reprocessing Plant. ■

Module-5

Cooling and Disposing of the Waste: Introduction, Classification of Waste Products, Fission Products and Their Biological Significance, Options for Nuclear Waste Disposal, Long-Term Storage and Disposal of Spent Nuclear Fuel, Storage and Disposal of Fission Products from Reprocessing Plants, Disposal of other Materials.
Fusion Energy - Prospect for the Future: Introduction, The Fusion Process, Confinement, Current Technical Position, Conclusions. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Introduction to Nuclear Power	Geoffrey F. Hewitt	Taylor & Francis	2000

(Group -3): 20ESE253 Carbon Capture and Storage

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Introduction: The carbon cycle, Mitigating growth of the atmospheric carbon inventory, The process of technology innovation.
Overview of carbon capture and storage: Carbon capture, Carbon storage.
Power generation fundamentals: Physical and chemical fundamentals, Fossil-fueled power plant, Combined cycle power generation, Future developments in power-generation technology. ■

Module-2

Carbon capture from power generation: Introduction, Precombustion capture, Postcombustion capture, Oxyfuel combustion capture, Chemical looping capture systems, Capture-ready and retrofit power plant, Approaches to zero-emission power generation.
Carbon capture from industrial processes: Cement production, Steel production, Oil refining, Natural gas processing.
Absorption capture systems: Chemical and physical fundamentals, Absorption applications in postcombustion capture, Absorption technology RD&D status. ■

Module-3

Adsorption capture systems: Physical and chemical fundamentals, Adsorption process applications, Adsorption technology RD&D status.
Membrane separation systems: Physical and chemical fundamentals, Membrane configuration and preparation and module construction, Membrane technology RD&D status, Membrane applications in precombustion capture, Membrane and molecular sieve applications in oxyfuel combustion, Membrane applications in postcombustion CO_2 separation, Membrane applications in natural gas processing. ■

Module-4

Cryogenic and distillation systems: Physical Fundamentals, Distillation column configuration and operation, Cryogenic oxygen production for oxyfuel combustion, Ryan–Holmes process for CO_2 –CH_4 separation, RD&D in cryogenic and distillation technologies.
Mineral carbonation: Physical and chemical fundamentals, Current state of technology development, Demonstration and deployment outlook.
Geological storage: Introduction, Geological and engineering fundamentals, Enhanced oil recovery, Saline aquifer storage, Other geological storage options. ■

Module-5

Ocean storage: Introduction, Physical, chemical, and biological fundamentals, Direct CO_2 injection, Chemical sequestration, Biological sequestration.
Storage in terrestrial ecosystems: Introduction, Biological and chemical fundamentals, Terrestrial carbon storage options, Full GHG accounting for terrestrial storage, Current R&D focus in terrestrial storage.
Other sequestration and use options: Enhanced industrial usage, Algal biofuel production.
Carbon dioxide transportation: Pipeline transportation, Marine transportation. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Carbon Capture and Storage	Stephen A. Rackley	Elsevier	2010

(Group -3): 20ESE331 Energy Storage in Power Grids

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Electrical Energy Storage: Difficulties of storing electrical energy, Need for storing electrical energy, Value enhancement of storage in electrical grids, Storage management.
Recent Developments in Energy Storage: Introduction, Storage technologies, Characteristics of a storage system, Hydraulic storage, Compressed-air storage, Thermal storage, Chemical storage, Kinetic storage, Electrostatic storage, Electromagnetic storage, Compared performances of storage technologies. ■

Module-2

Applications and Values of Energy Storage in Power Systems: Introduction, Introduction to power systems and their operation, Services that can be provided by storage, Example of the contribution of storage to the treatment of congestion events. ■

Module-3

Applications and Values of Energy Storage in Power Systems (continued): Example of contribution of storage to dynamic support of frequency control in an island grid, General conclusion.
Introduction to Fuzzy Logic and Application to the Management of Kinetic Energy Storage in a Hybrid Wind-Diesel System: Introduction, Introduction to fuzzy logic, Wind-kinetic energy storage combination on an isolated site with a diesel generator. ■

Module-4

Supervisor Construction Methodology for a Wind power Source Combined with Storage: Introduction, Energetic system studied, Supervisor development methodology, Specifications, Supervisor structure, Identification of various operating states: functional graph, Membership functions, Operational graph, Fuzzy rules, Experimental validation. ■

Module-5

Design of a Hybrid Multisource/Multistorage Supervisor: Introduction, Methodology for the construction of a supervisor for a hybrid source incorporating wind power, Compared performance of different variants of hybrid source.
Management and Economic Enhancement of Adiabatic Compressed-Air Energy Storage Incorporated into a Power Grid: Introduction, Services provided by storage, Supervision strategy,
Economic value of services, Application. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Energy Storage in Electric Power Grids	Benoît Robyns et al	Wiley	2015

(Group -3): 20EMS241 Nonlinear Systems	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Nonlinear Systems: Introduction to Nonlinear systems, Behavior of Nonlinear Systems- Frequency –Amplitude dependence, Jump resonance, Sub- harmonic oscillations, Frequency entrainment, Limit Cycles, Asynchronous quenching. Common Physical Non-linearities, Classification of nonlinearities, methods of analysis of nonlinear systems Definition of describing function, Linearization of nonlinear system. ■

Module-2

Describing Function Method: Introduction, assumptions and definition, evaluation of describing function for functions like x2, x3,|x|x and common nonlinearities like relay, saturation, dead zone, hysteresis, backlash and a combination of these, Analysis of nonlinear systems – Concept of enclosure, stable and unstable limit cycles, Review of polar plot and Nichols Plot, Evaluation of existence of limit cycle and calculation of magnitude and frequency of oscillation. ■

Module-3

Phase-Plane Analysis: Introduction to phase plane and phase trajectory, Singular points –evaluation, classification and trajectories, Stability analysis of nonlinear system using phase trajectories, Limit cycles in phase portrait, Construction of phase trajectories - Analytical method, Isocline method, Delta method, and Pell's method. ■

Module-4

Lyapunov Stability: Stability Definitions, Some Preliminaries, Lyapunov's Direct Method, Stability of Linear Systems, Lyapunov's Linearization Method, The Lur'e Problem, Krasovskii;s method of stability assessment, Variable gradient method of stability assessment. Stability assessment of discrete time systems. ■

Module-5

Stability Assessment in the Frequency Domain: Circle criteria and its application, Popov's method.
Sliding mode control: Introduction An overview of classical sliding mode control, introductory example, Dynamics in sliding mode – Linear Systems, Nonlinear Systems, Chattering Problems, Reachability Condition, Applications of Sliding mode control. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.

Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

1	Advanced Control Theory	A.NagoorKani	RBA Publications	2nd Edition, 2009
2.	Nonlinear Systems Analysis	M. Vidyasagar	PHI	2nd Edition. 2002
3	Non Linear Systems	H. K. Khalil	Pearson	2015
4.	Sliding Mode Control in Engineering	Wilfrid Perruquetti & Jean Pierre Barbot	Marcel Dekker	2002

(Group -3): 20EMS243 Control Systems for HVAC

Exam Hours: 3 hours | **Exam Marks(Maximum):100**

Module-1

Control Theory and Terminology: Introduction, Elementary Control System, Purposes of Control, Control action, Energy Sources for Control, Systems, Measurement, Symbols and Abbreviations, Psychrometrics, Relationships.
Pneumatic Control Devices: Introduction, Pneumatic Control Devices, Control Cabinets, Air Supply.
Electric and Electronic Control: Devices, Electric Control Devices, Electronic Control Devices. ■

Module-2

Fluidic Control Devices: Introduction, Wall Attachment Devices, Turbulence Amplifiers, Vortex Amplifiers, Radial Jet Amplifier, Fluidic Transducers, Manual Switches.
Flow Control Devices: Dampers, Steam and Water Flow, Control Valves.
Elementary Control Systems: Introduction, Outside Air Controls, Air Stratification, Heating, Cooling Coils, Humidity Control, Dehumidifiers, Static Pressure Control, Electric Heat, Gas-Fired Heaters, Oil-Fired Heaters, Refrigeration Equipment, Fire and Smoke Control, Electrical Interlocks, Location of Sensors. ■

Module-3

Complete Control Systems: Introduction, Single-Zone Systems, Multizone Air Handling Systems, Dual-Duct Systems, Variable-Volume Systems, Reheat Systems, Heat Reclaim, Fan-Coil Units, Induction Systems, Unit Ventilators, Packaged Equipment, Other Packaged Equipment, Radiant Heating and Cooling, Radiators and Convectors, Heat Exchangers, Solar Heating and Cooling Systems. ■

Module-4

Electric Control Systems: Introduction, Electric Control Diagrams, Electrical Control of a Chiller, Electrical Control of an Air Handling Unit, Example: A Typical Small Air- Conditioning System, Electric Heaters, Reduced-Voltage Starters, Multispeed Starters, Variable Speed Controllers.
Special Control: Introduction, Close Temperature and/or Humidity Control, Controlled Environment, Rooms for Testing.
Digital and Supervisory Control Systems: Introduction, Hard-Wired Systems, Multiplexing Systems, Computer-Based Systems for Monitoring and Control, Benefits of the Computer System, Training for Maintenance and Operation. ■

Module-5

Psychrometrics: Introduction, Psychrometric Properties, Psychrometric Tables, Psychrometric Charts, Processes on the Psychrometric Chart, HVAC Cycles on the Chart, Impossible Processes, Effects of Altitude.
Central Plant Pumping and Distribution Systems: Introduction, Diversity, Constant Flow Systems, Variable Flow Systems, Distribution Systems, Building Interfaces.
Retrofit of Existing Control Systems: Introduction, Economic Analysis, Discriminators, Control Modes, Economy Cycle Controls, Single-Zone systems, Reheat Systems, Multizone Systems, Dual-Duct Systems, Systems with Humidity Control, Control Valves and Pumping Arrangements.
Dynamic Response And Tuning: Introduction, Dynamic Response, Tuning HVAC Control Loops. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.

Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Control Systems For Heating, Ventilating, and Air Conditioning	Roger W. Haines	Springer	6th Edition, 2006

(Group -3): 20EMS333 Nanotechnology for Microelectronics and Optoelectronics

Exam Hours: 3 hours | **Exam Marks(Maximum):100**

Module-1

Mesoscopic Physics and Nanotechnologies: Trends in nanoelectronics and Optoelectronics, Characteristic lengths in mesoscopic systems, Quantum mechanical coherence, Quantum wells, wires, and dots, Density of states and dimensionality, Semiconductor heterostructures, Quantum transport.

Survey of Solid State Physics: Introduction, review of quantum mechanics, free electron model of a solid. Density of states function, Bloch theorem, Electrons in crystalline solids, Dynamics of electrons in bands, Lattice vibrations, Phonons. ■

Module-2

Review of Semiconductor Physics: Introduction, Energy bands in typical semiconductors, Intrinsic and extrinsic semiconductors, Electron and hole concentrations in semiconductors, Elementary transport in semiconductors, Degenerate semiconductors, Optical properties of semiconductors.

The Physics of Low-Dimensional Semiconductors: Introduction, Basic properties of two-dimensional semiconductor nanostructures, Square quantum well of finite depth, Parabolic and triangular quantum wells, Quantum wires, Quantum dots, Strained layers, Effect of strain on valence bands, Band structure in quantum wells, Excitonic effects in quantum. ■

Module-3

Semiconductor Quantum Nanostructures and Superlattices: Introduction, MOSFET structures, Heterojunctions, Quantum wells, Superlattices.

Electric Field Transport in Nanostructures: Introduction, Parallel transport, Perpendicular transport, Quantum transport in nanostructures. ■

Module-4

Transport in Magnetic Fields and the Quantum Hall Effect: Introduction, Effect of a magnetic field on a crystal, Low-dimensional systems in magnetic fields, Density of states of a 2D system in a magnetic field, The Aharonov–Bohm effect, The Shubnikov–de Haas effect, The quantum Hall Effect.

Optical and Electro-optical Processes in Quantum Heterostructures: Introduction, Optical properties of quantum wells and superlattices, Optical properties of quantum dots and nanocrystals, Electro-optical effects in quantum wells. Quantum confined Stark Effect, Electro-optical effects in superlattices. Stark ladders and Bloch Oscillations. ■

Module-5

Electronic Devices Based on Nanostructures: Introduction, MODFETs, Heterojunction bipolar transistors, Resonant tunnel effect, Hot electron transistors, Resonant tunneling transistor, Single electron transistor.

Optoelectronic Devices Based on Nanostructures: Introduction, Heterostructure semiconductor lasers, Quantum well semiconductor lasers, Vertical cavity surface emitting lasers (VCSELs), Strained quantum well lasers, Quantum dot lasers, Quantum well and superlattice photodetectors, Quantum well modulators. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.

Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Nanotechnology for Microelectronics and Optoelectronics	J.M. Martínez-Duart, R.J. Martín-Palma, F. Agulló-Rueda	Elsevier	2006

(Group -3): 20EMS331 Microelectronic Fabrication	
Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Introduction: Historical Perspective, Overview of Monolithic Fabrication, Metal – Oxide Semiconductor (MOS) Process, Basic Bipolar Process, Safety.
Lithography: The Photolithographic Process, Etching Techniques, Photomask Fabrication, Exposure Systems, Exposure Sources, Optical and Electron Microscopy.
Thermal Oxidation of Silicon: The Oxidation Process, Modelling Oxidation, Factors Influencing Oxidation Rate, Dopant Redistribution during Oxidation, Masking Properties of Silicon Dioxide, Technology of Oxidation, Oxide Quality, Selective Oxidation and Shallow Trench Formation, Oxide Thickness Characterization, Process Simulation.■

Module-2

Diffusion: The Diffusion Process, Mathematical Model for Diffusion, The Diffusion Coefficient, Successive Diffusions, Solid – Solubility Limits, Junction Formation and Characterization, Sheet Resistance, Generation – Depth and Impurity Profile Measurement, Diffusion Simulation, Diffusion Systems, Gettering. ■

Module-3

Ion Implantation: Implantation Technology, Mathematical Model for Ion Implantation, Selective Implantation, Junction Depth and Sheet Resistance, Channeling, Lattice, Damage and Annealing, Shallow Implantations.
Film Deposition: Evaporation, Sputtering, Chemical Vapour Deposition, Epitaxy.
Interconnections and Contacts: Interconnections in Integrated Circuits, Metal Interconnections and Contact Technology, Diffused Interconnections, Polysilicon Interconnections and Buried Contacts, Silicides and Multilayer – Contact Technology, The Liftoff Process, Multilevel Metallization, Copper Interconnects and Damascene Process.■

Module-4

Packaging and Yield: Testing, Water Thinning and Die Separation, Die Attachment, Wire Bonding, Packages, Flip – Chip and tape – Automated – Bonding Process, Yield.
MOS Process Integration: Basic MOS Device Considerations, MOS Transistor Layout and Design Rules, Complementary MOS (CMOS) Technology, Silicon on Insulator. ■

Module-5

Bipolar Process Integration: The Junction – Isolated Structure, Current Gain, Transit Time, Base Width, Breakdown Voltages, Other Elements in SBC Technology, Layout Considerations, Advanced Bipolar Structure, Other Bipolar Insulation Techniques, BICMOS.
Process for Microelectromechanical Systems (MEMS): Mechanical Properties of Silicon, Bulk Micromachining, Silicon Etchants, Surface Micromachining, High – Aspect – Ratio Micromachining, Silicon Wafer Bonding, IC Process Compatibility.■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Introduction to Microelectronic Fabrication	Richard C Jaeger	Prentice Hall	2nd Edition, 2002

(Group -4): 20EPS243 Restructured Power Systems

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Deregulation of the Electricity Supply Industry: Introduction, Meaning of Deregulation, Background to Deregulation and the Current Situation around the World, Benefits from a Competitive Electricity Market, After Effects of Deregulation.

Power System Economic Operation Overview: Introduction, Economical Load Dispatch, Optimal Power Flow as a Basic Tool, Unit Commitment, Formation of Power Pools. ■

Module-2

Power System Operation in Competitive Environment: Introduction, Role of Independent System Operator (ISO), Operational Planning Activities of ISO, Operational Planning Activities of a Genco. ■

Module-3

Transmission Open Access and Pricing Issues: Introduction, Power Wheeling, Transmission Open Access, Cost Components in Transmission, Pricing of Power Transactions, Transmission Open Access and Pricing Mechanisms in Various Countries, Developments in International Transmission Pricing in Europe, Security Management in Deregulated Environment, Congestion Management in Deregulation. ■

Module-4

Ancillary Services Management: Ancillary Services and Management in Various Countries, Reactive Power as an Ancillary Service. ■

Module-5

Reliability and Deregulation: Terminology, Reliability Analysis, Network Model, Reliability Costs, Hierarchical Levels, Reliability and Deregulation, Performance Indicators. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Operation of Restructured Power Systems	Kankar Bhattacharya et al	Kluwer Academic	2001

(Group -4): 20EPS333 Substation Automation Systems	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Prerequisites of Networking Technology: Computer Network, Network Topology, Network Structure, Communication Protocols, Geographical Scale of Network, Internetwork, Network Structure, Communication System, Object-Oriented Programming, Programming Tool or Software Development Tool. (Please refer to appendix C of the prescribed textbook before you start with Module-1)

Module-1

Evolution of Substation Automation Systems (SASs): Emerging Communication Technologies, Intelligent Electronic Devices (IEDs), Networking Media, Communication Standards.
Main Functions of Substation Automation Systems: Control Function, Monitoring Function, Alarming Function, Measurement Function, Setting and Monitoring of Protective Relays, Control and Monitoring of the Auxiliary Power System, Voltage Regulation.
Impact of the IEC 61850 Standard on SAS Projects: Impact on System Implementation Philosophy, Impact on User Specification, Impact on the Overall Procurement Process, Impact on the Engineering Process, Impact on Project Execution, Impact on Utility Global Strategies, The Contents of the Standard, Dealing with the Standard.
Switchyard Level, Equipment and Interfaces: Primary Equipment, Medium and Low Voltage Components, Electrical Connections between Primary Equipment, Substation Physical Layout, Control Requirements at Switchyard Level. ■

Module-2

Bay Level: Components and Incident Factors: Environmental and Operational Factors, Insulation Considerations in the Secondary System, Switchyard Control Rooms, Attributes of Control Cubicles,
The Bay Controller (BC), Other Bay Level Components, Process Bus.
Station Level: Facilities and Functions: Main Control House, Station Controller, Human Machine Interface HMI, External Alarming, Time Synchronization Facility, Protocol Conversion Task, Station Bus, Station LAN. ■

Module-3

System Functionalities: Control Function, Monitoring Function, Protection Function, Measuring Function, Metering Function, Report Generation Function, Device Parameterization Function.
System Inputs and Outputs: Signals Associated with Primary Equipment, Signals Associated with the Auxiliary Power System, Signals Associated with Collateral Systems.
System Engineering: Overall System Engineering, Bay Level Engineering, Station Level Engineering, Functionalities Engineering, Auxiliary Power System Engineering, Project Drawings List, The SAS Engineering Process from the Standard IEC 61850 Perspective. ■

Module-4

Communication with the Remote Control Center: Communication Pathway, Brief on Digital Communication, Overview of the Distributed Network Protocol (DNP3).
System Attributes: System Concept, Network Topology, Redundancy Options, Quality Attributes,
Provisions for Extendibility in Future, Cyber-Security Considerations, SAS Performance requirements.
Tests on SAS Components: Type Tests, Acceptance Tests, Tests for Checking the Compliance with the Standard IEC 61850.
Factory Acceptance Tests (FATs): Test Arrangement, System Simulator, Hardware Description, Software Identification, Test Instruments, Documentation to be Available, Checking System Features, Planned Testing Program for FAT, Nonstructured FATs, After FATs.
Commissioning Process: Hardware Description, Software Identification, Test Instruments,
Required Documentation, Engineering Tools, Spare Parts, Planned Commissioning Tests, Nonstructured Commissioning Tests, List of Pending Points, Re-Commissioning. ■

Module-5

Training Strategies for Power Utilities: Project-Related Training, Corporate Training.
Planning and Development of SAS Projects: System Specification, Contracting Process, Definition of the Definitive Solution, Design and Engineering, System Integration, Factory Acceptance Tests, Site Installation, Commissioning Process, Project Management, Security Issues, Documentation and Change Control.
Quality Management for SAS Projects: Looking for Quality- in Component Capabilities and Manufacturing, during the Engineering Stage, in the Cubicle Assembly Stage, during FAT, during Installation and Commissioning, Use of Appropriate Device Documentation.
SAS Engineering Process According to Standard IEC 61850: SCL Files, Engineering Tools, Engineering Process.

Future Technological Trends: Toward the Full Digital Substation, Looking for New Testing Strategies on SAS Schemes, Wide Area Control and Monitoring Based on the IEC/TR 61850–90–5, Integration of IEC 61850 Principles into Innovative Smart Grid Solutions. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Substation Automation Systems Design and implementation	Evelio Padilla	Wiley	2020

(Group -4): 20EPS332 Integration Of Renewable Energy

Exam Hours: 3 hours | **Exam Marks(Maximum):100**

Module-1

Smart Grid Distributed Generation Systems: Introduction, DC Architecture for Design of a 2 MVA PV Station, PV Modules, Architecture for design of a 2 MVA PV Station, DG System Operating as Part of Utility Power System Power System Reactive Power (VAR) Control, An Inverter is also a Three Terminal Device, The Smart Grid PV –UPS DG System, The Smart Grid Split DC Bus UPS – PV DG System, The Island Mode of Operation, The Parallel Operation of Inverters, The Inverter Operating as steam Unit, The Problem of Power Quality.
Inverter Control Voltage and Current Distributed Generation Systems: Power converter system, Control Theory, Control System Development, Step-By-Step Control Flow Explanations.■

Module-2

Parallel Operation of Inverters in Distributed Generation Systems: Introduction, Distributed Energy System Description, DGS Control Requirements, Distributed Generation System Modelling, Control System Design, Proposed Load Sharing Control Algorithm, Simulation Results.
Power Converter Topologies for Distributed Generation Systems: Introduction, Distributed Generation Systems, Voltage and Current Control of Individual Inverters in Island Mode, The System Topology, Newton–Raphson Method. ■

Module-3

Voltage and Current Control of three-Phase Four-Wire Distributed Generation (DG) Inverter in Island Mode: The Plant Modelling, The Basic Mathematical Model, Transform the Model into Stationary Reference Frame, Convert to Per-Unit System, Control System Development, Design of the Discrete-Time Sliding Mode Current Controller, Design of the Robust Servomechanism Voltage Controller, Limit the Current Command, A Modified Space Vector PWM, Performances and Analysis—Frequency Domain Analysis.■

Module-4

Voltage and Current Control of three-Phase Four-Wire Distributed Generation (DG) Inverter in Island Mode (continued): Experimental Results—The Experimental Setup, The Robust Stability: Basic Ideas About Uncertainty, Robust Stability, and M – Analysis.
Power Flow Control of a Single Distributed Generation Unit: Introduction, Control System, Voltage and Current Control, Real and Reactive Power Control Problems, The Conventional Integral Control, The Stability Problem, Newton–Raphson Parameter Estimation and Feedforward Control Newton–Raphson Parameter Identification, Harmonic Power Control, Simulation Results, Experimental Results. ■

Module-5

Robust Stability Analysis of Voltage and Current Control for Distributed Generation Systems: Introduction, The Stability Problem, Robust Stability Analysis using Structured Singular Value μ, Tuning the Controller Performance.
PWM Rectifier Control for Three-Phase Distributed Generation System: Introduction, System Analysis, The Control Strategy, Simulation Results, Experimental Results.■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Integration of Green and Renewable Energy in Electric Power Systems	Ali Keyhani	Wiley	2010

(Group -4): 20EPS21 EHV AC Transmission	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Transmission Line Trends and Preliminaries: Role of EHV AC Transmission, Standard Transmission Voltages, Average Values of Line Parameters, Power-Handling Capacity and Line Loss, Examples of Giant Power Pools and Number of Lines, Costs of Transmission Lines and Equipment, Mechanical Considerations in Line Performance.
Calculation of Line and Ground Parameters: Resistance of Conductors, Temperature Rise of Conductors and Current-Carrying Capacity, Properties of Bundled Conductors, Inductance of EHV Line Configurations, Line Capacitance Calculation, Sequence Inductances and Capacitances, Line Parameters for Modes of Propagation, Resistance and Inductance of Ground Return. ■

Module-2

Voltage Gradients of Conductors: Electrostatics, Field of Sphere Gap, Field of Line Charges and Their Properties, Charge-Potential Relations for Multi-Conductor lines, Surface Voltage Gradient on Conductors, Examples of Conductors and Maximum Gradients on Actual Lines, Gradient Factors and Their Use, Distribution of Voltage Gradient on Sub-conductors of Bundle, Design of Cylindrical Cages for Corona Experiments, Voltage Gradients on Conductors in the Presence of Ground Wires on Towers. ■

Module-3

Corona: I^2R Loss and Corona Loss, Corona-Loss formulae, Attenuation of Travelling Waves due to Corona Loss, Audible Noise: Generation and Characteristics, Limits for Audible Noise. Generation of Corona Pulses and their Properties, Properties of Pulse Trains and Filter Response, Limits for Radio Interference Fields.
Theory of Travelling Waves and Standing Waves: Travelling Waves and Standing Waves at Power Frequency, Differential Equations and Solutions for General Case, Standing Waves and Natural Frequencies, Open-Ended Line: Double-Exponential Response, Open-Ended Line: Response to Sinusoidal Excitation, Line Energization with Trapped-Charge Voltage, Corona Loss and Effective Shunt Conductance, The Method of Fourier Transforms, Reflection and Refraction of Travelling Waves, Transient Response of Systems with Series and Shunt Lumped Parameters and Distributed Lines, Principles of Travelling-Wave Protection of EHV Lines.■

Module-4

Lightning and Lightning Protection: Lightning Strokes to Lines, Lightning-Stroke Mechanism, General Principles of the Lightning-Protection Problem, Tower-Footing Resistance, Insulator Flashover and Withstand Voltage, Probability of Occurrence of Lightning-Stroke Currents, Lightning Arresters and Protective Characteristics, Dynamic Voltage Rise and Arrester Rating, Operating Characteristics of Lightning Arresters, Insulation Coordination Based on Lightning.
Over voltages in EHV Systems Caused by Switching Operations: Origin of Overvoltages and Their Types, Short-Circuit Current and the Circuit Breaker, Recovery Voltage and the Circuit Breaker, Overvoltages Caused by Interruption of Low Inductive Current, Interruption of Capacitive Currents, Ferro-Resonance Overvoltages, Calculation of Switching Surges—Single Phase Equivalents, Distributed-Parameter Line Energized by Source, Generalized Equations for Single-Phase Representation, Generalized Equations for Three-Phase Systems, Inverse Fourier Transform for the General Case, Reduction of Switching Surges on EHV Systems, Experimental and Calculated Results of Switching-Surge Studies. ■

Module-5

Power-Frequency Voltage Control and Over voltages: Problems at Power Frequency, Generalized Constants, No-Load Voltage Conditions and Charging Current, The Power Circle Diagram and Its Use, Voltage Control Using Synchronous Condensers, Cascade Connection of Components—Shunt and Series Compensation, Sub-Synchronous Resonance in Series-Capacitor Compensated Lines, Static Reactive Compensating Systems (Static VAR), High Phase Order Transmission.
Design of EHV Lines Based upon Steady-State Limits and Transient Overvoltages: Introduction, Design Factors Under Steady State, Design Examples: Steady-State Limits, Design Examples I to IV, Line Insulation Design Based Upon Transient Overvoltages.■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook				
1	Extra High Voltage AC Transmission Engineering	Rakosh Das Begamudre	New Age International Publishers.	4th Edition,2011

(Group -4): 20EPE21 Electric Drives

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Characteristics Electric motors: Introduction, Characteristics of DC motors, Three phase Induction Motors and Synchronous Motors, Braking of Electric Motors.■

Module-2

Dynamics of Electric Drives: Introduction, Classification of Electric Drives, Basic Elements of an Electric Drive, Dynamic Conditions of Drive System, Stability Considerations of Electric Drive.
Control of Electric Motors: Induction Motor Drives. ■

Module-3

Control of Electric Motors (continued): Synchronous Motor Drives, DC Drives. Permanent Magnet Synchronous Motor, Classification of Permanent Magnet Synchronous Motor, Cycloconverters fed Synchronous Motor. ■

Module-4

Control of Electric Motors (continued): Permanent Magnet Synchronous Motor, Classification of Permanent Magnet Synchronous Motor, Cycloconverters fed Synchronous Motor.
Applications: Drive Considerations foe Textile Mills, Steel Rolling Mills, Cranes and Hoist Drives, Cement Mills, Sugar Mills, Machine Tools, Paper Mills, Coal Mines, Centrifugal Pumps, Turbo - compressors. ■

Module-5

Microprocessors and Control of Electrical Drives: Introduction, Dedicated Hardware Systems versus Microprocessor Control, Applications Area and Functions of Microprocessors in Drive Technology, Control of Electric Drives using Microprocessors, Control System Design of Microprocessors based Variable Speed Drives, Stepper motors. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Electric Drives Concepts and Applications	Vedam Subrahmanyam	Mc Graw Hill	2^{nd} Edition, 2020

(Group -4): 20ECD21 AC and DC Drives – 2

Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Frequency – Controlled Induction Motor Drives: Current Source Induction Motor Drives, Applications.
Vector Controlled Motor Drives: Introduction,Principal of Vector Control, Direct Vector Control, Derivation of Indirect Vector Control Scheme, Indirect Vector - Control Scheme, Implimentation of an Indirect Vector Control Scheme, Tunig of the Vector Controller, Flow Chart for Dynamic Computation, Dynamic Simulation Results. ■

Module-2

Vector Controlled Motor Drives (continued): Parameter Sensitivity of the Indirect Vector – Controlled Induction Motor Drive, Parameter Sensitivity Compensation, Flux Weaking Operation, Speed – controller Design for an Indirect Vector – Controlled Induction Motor Drive, Performance and Applications.
Permanent – Magnet Synchronous Motor: Introduction, Permanent Magnet (PM) and Characteristics, Synchronous Machines with PMs, Vector Control of PM Synchronous Motor. ■

Module-3

Permanent – Magnet Synchronous Motor (continued): Control Strategies, Flux Weakening Operation, Speed Controller Design, Sensorless Control, Parameter Sensitivity.
PM Brushless DC Motor (PMBDCM) – Modelling of PMBDCM, Drive scheme, Dynamic Simulation.■

Module-4

Switched Reluctance Drive Systems: Basic Machine Concepts, Operating Principles, Multi-Phase Machines, Control of Switched Reluctance Drives, Switched Reluctance Demonstration Machine. ■

Module-5

Expert System, Fuzzy Logic, and Neural networks for Drives: Introduction, Expert System, Fuzzy Logic, Neural Network. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

1	Electric Motor Drives: Modelling: Analysis, and Control	R. Krishnan	Pearson	2020
2	Advanced Electrical Drives Analysis, Modelling, Control	Rik De Doncker Duco W.J. Pulle André Veltman	Springer	2011
3	Power Electronics and Variable Frequency Drives Technology and Applications	Bimal K. Bose	Wiley	Reprint 2013

(Group -4): 20ECD331 PLC Applications in Electric Drives	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

INTRODUTION: Introduction to Programmable logic controller (PLC), role in automation (SCADA), Advantages and disadvantages, hardware, internal architecture, sourcing and sinking, characteristics of I/O Devices, list of input and output devices, examples of applications. I/O processing, input/output units, signal Conditioning, remote connections, networks, processing inputs I/O addresses.
PROGRAMMING: Ladder programming- ladder diagrams, logic functions, latching, multiple outputs, Entering programs, functional blocks, programme examples like location of stop and emergency switches. ■

Module-2

PROGRAMMING LANGUAGES: Instruction list, sequential functions charts and structured text, jump And call subroutines**.**
INTERNAL RELAYS: ladder programmes, battery- backed relays, one - shot operation, set and reset, Master control relay. ■

Module-3

Programming Timers: Mechanical timing relays, timer instructions, on-delay timer instructions, off-delay timer instructions, retentive timer, cascading timer.
Programming counters: Counter instructions, up-counter, down-counter, cascading counters, incremental encoder-counter applications, combining counter and timer functions■

Module-4

Program control instructions: Master control reset instructions, jump instructions, subroutine functions, immediate input and immediate output instructions, forcing external I/O addresses, safety circuitry, selectable timed interrupt, fault routine, temporary end instructions, suspend instruction. Data manipulation instruction, math instruction.
Sequencer and Shift register instructions: Mechanical sequencer, sequencer instructions, sequencer programs, bit shift registers, word shift operations. ■

Module-5

PLC installation practices, editing and troubleshooting: Leaky inputs and outputs, grounding, program editing and commissioning, programming and monitoring, voltage variations and searches. Applications of PLC in controlling DC motors control of induction motors using PLC. ■

Question paper pattern:
The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module. ■

Text/Reference Books

1. Programmable Logic controllers, Frank D. Petruzella, McGraw Hill, 4th Edition, 2020.
2. Programmable Logic controllers, W Bolton, Elsevier- newness, 5th Edition, 2009.
3. Programmable logic controllers - principles and applications, John W Webb, Ronald A Reis, Pearson education, 5th Edition, 2007.
4. Programmable Controller Theory and Applications, A Bryan, E. A Bryan, An industrial text Company publication, 2nd edition, 1997.
5. Programmable Controllers, an Engineers Guide, E. A Paar, Newness, 3rd edition, 2003.

(Group -4): 20ECD252 Electric Drive Design

Exam Hours: 3 hours | **Exam Marks(Maximum):100**

Module-1

Electric Drive Components: Definition, Electric drive components.
Driven Bodies: Function of the driven body, Reference or rated running, Transient behaviour, Specifications.
Transmission: Transmission types and characterization, Resolution, Speed adaptation, Dynamic behaviour, Oscillatory torque, Position transfer. ■

Module-2

Motors: Characterization, Rotating and linear motors, Induction motors, DC motors, Synchronous motors, Variable reluctance motors, Linear motors, Piezoelectric motors and actuators, BLDC motor characteristics. ■

Module-3

Motors - Characterization: Characteristics, Scaling laws, Parametric expression.
Global Design of an Electric Drive: Introduction, Dynamic equations, Example. ■

Module-4

Heating and Thermal Limits: Heating importance, Thermal equations, Energy dissipated at start-up, Cooling modes.
Electrical Peripherals: Adaptation, Sources, Voltage adjustment, Current adjustment devices.
Electronic Peripherals: Power electronic, Simple switch, H bridge, Element bridge. ■

Module-5

Sensors: Functions and types, Optical position sensors, Hall sensors, Inductive position sensors, Resolver-type rotating, inductive, contactless sensors, Other position sensors, The motor as a position sensor, Sensor position, Current sensors, Protection sensors.
Direct Drives: Performance limits, Motor with external rotor, Example.
Integrated Drives: Principle, Realization. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Electric Drives	Marcel Jufer	Wiley	2010

(Group -4): 20ECD323 Sensorless AC Motor Control

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Dynamical Models of AC Machines: Applications of AC Machines, Electric Vehicles: Traction System, The Concordia/Clark and Park Transformations, Permanent Magnet Synchronous Motor, Induction Motor, Operating Conditions and Benchmark, Conclusions. ■

Module-2

Observability Property of AC Machines: Observability Property of AC Machines, Observability, Permanent Magnet Synchronous Motor, Induction Motor Observability Analysis, Normal Forms for Observer Design, Conclusions. ■

Module-3

Observer Design for AC Motors: Observers for Nonlinear Systems, PMSM Adaptive Interconnected Observers, High Order Sliding Mode Observers for PMSM, Adaptive Interconnected Observer for the Induction Motor, Conclusions. ■

Module-4

Robust Synchronous Motor Controls Designs (PMSM and IPMSM): Backstepping Control, High-Order Sliding Mode Control, Conclusions.

Robust Induction Motor Controls Design (IM): Field-Oriented Control, Integral Backstepping Control and Field-Oriented Control, High-Order Sliding Mode Control, Conclusions. ■

Module-5

Sensorless Output Feedback Control for SPMSM and IPMSM: Robust Adaptive Backstepping Sensorless Control, Robust Adaptive High Order Sliding Mode Control, Conclusions.

Sensorless Output Feedback Control for Induction Motor: Classical Sensorless Field-Oriented Control, Robust Adaptive Observer-Backstepping Sensorless Control, Robust Adaptive High Order Sliding Mode Control, Conclusions.■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Sensorless AC Electric Motor Control Robust Advanced Design Techniques and Applications	Alain Glumineau et al	Springer	2015

(Group -4): 20ESE21 Integration of Distributed Generation

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Distributed Generation: Introduction, Sources of Energy - Wind Power, Solar Power, Combined Heat-and-Power, Hydropower, Tidal Power, Wave Power, Geothermal Power, Thermal Power Plants.■

Module-2

Distributed Generation (continued): Interface with the Grid.
Power System Performance: Impact of Distributed Generation on the Power System, Aims of the Power System, Hosting Capacity Approach, Power Quality, Voltage Quality and Design of Distributed Generation, Hosting Capacity Approach for Events, Increasing the Hosting Capacity.
Overloading and Losses: Impact of Distributed Generation, Overloading: Radial Distribution Networks, Overloading: Redundancy and Meshed Operation, Losses. ■

Module-3

Overloading and Losses (continued): Increasing the Hosting Capacity.
Voltage Magnitude Variations: Impact of Distributed Generation, Voltage Margin and Hosting Capacity, Design of Distribution Feeders, A Numerical Approach to Voltage Variations, Tap Changers with Line-Drop Compensation, Probabilistic Methods for Design of Distribution Feeders.■

Module-4

Voltage Magnitude Variations (continued): Statistical Approach to Hosting Capacity, Increasing the Hosting Capacity.
Power Quality Disturbances: Impact of Distributed Generation, Fast Voltage Fluctuations, Voltage Unbalance.■

Module-5

Power Quality Disturbances (continued): Low-Frequency Harmonics, High-Frequency Distortion, Voltage Dips, Increasing the Hosting Capacity. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Integration of Distributed Generation in the Power System	Math Bollen	Wiley	2011

(Group -4): 20ESE244 Environmental Impacts of Renewable Energy	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**
Module-1	
Energy Basics: Energy, Types of Energy, Non-renewable Energy, Renewable Energy, Measuring Energy, Heat Engines. **Wind Power:** Introduction, Wind Power Basics, Wind Energy, Wind Power, Wind Turbine Components, Wind Energy Site Evaluation Impacts, Wind Energy Construction Impacts. ■	
Module-2	
Wind Power(continued): Wind Energy Operations Impacts, Wind Energy Impacts on Wildlife, Wind Energy Impacts on Human Health, Power Transmission Lines, Energy Transmission Site Evaluation Impacts, Energy Transmission Construction Impacts, Energy Transmission Operations Impacts, Wind Turbine Operations and Maintenance Personnel Safety Concerns, Wind Power: The Bottom Line. **Solar Energy:** Energy from the Sun, Environmental Impacts of Solar Energy, Ecological Impacts, Solar Energy Job Hazards. ■	
Module-3	
Hydropower: River, Historical Perspective, Key Definitions, Hydropower Basic Concepts, Advanced Hydropower Technology, Ecological Impacts of Hydropower, Biological Impacts of Flow Fluctuations, Low Water Levels and Evaporation of Reservoirs, Impacts on Human Health and Safety, Hydropower: The Bottom Line. ■	
Module-4	
Biomass/Bioenergy: Introduction, Biomass, Plant Basics, Feedstocks, Biomass for Biopower Biomass for Bioproducts. ■	
Module-5	
Biomass/Bioenergy(continued): Biodiesel, Biogas (Methane), Impacts of Biomass Construction, Production, and Operation, Impacts on Human Health and Safety, Fatalities and Incidents, Biofuels: The Bottom Line. **Fuel Cells:** Introduction to Hydrogen Fuel Cells, Hydrogen Storage, How a Hydrogen Fuel Cell Works, Environmental Impacts of Fuel Cells, Properties of Hydrogen. ■	
Question paper pattern: The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60. • The question paper will have ten full questions carrying equal marks. • Each full question is for 20 marks. • There will be two full questions (with a maximum of four sub questions) from each module. • Each full question will have sub question covering all the topics under a module. • The students will have to answer five full questions, selecting one full question from each module. ■	
Textbook	
1. Environmental Impacts of Renewable Energy, Frank R. Spellman, CRC Press, 2015.	

(Group -4): 20EMS22 High Speed VLSI Design

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Preliminary Concepts: Interconnections for VLSI Applications, Copper Interconnections, Method of Images, Method of Moments, Even- and Odd-Mode Capacitances, Transmission Line Equations, Miller's Theorem, Inverse Laplace Transformation, Resistive Interconnection as Ladder Network, Propagation Modes in Micro strip Interconnection, Slow-Wave Mode Propagation, Propagation Delays.

Parasitic Resistances, Capacitances, and Inductances: Parasitic Resistances: General Considerations, Parasitic Capacitances: General Considerations, Parasitic Inductances: General Considerations, Approximate Formulas for Capacitances. ■

Module-2

Parasitic Resistances, Capacitances, and Inductances (continued): Green's Function Method: Using Method of Images, Green's Function Method: Fourier Integral Approach, Network Analog Method, Simplified Formulas for Interconnection Capacitances and Inductances on Silicon and GaAs Substrates, Inductance Extraction Using FastHenry, Copper Interconnections: Resistance Modeling, Electrode Capacitances in GaAs MESFET:Application of Program IPCSGV. ■

Module-3

Interconnection Delays: Metal–Insulator–Semiconductor Microstripline Model of an Interconnection, Transmission Line Analysis of Single-Level Interconnections, Transmission Line Analysis of Parallel Multilevel Interconnections, Analysis of Crossing Interconnections, Parallel Interconnections Modelled as Multiple Coupled Microstrips. ■

Module-4

Interconnection Delays (continued): Modelling of Lossy Parallel and Crossing Interconnections as Coupled Lumped Distributed Systems, Very High Frequency Losses in Microstrip Interconnection, Compact Expressions for Interconnection Delays, Interconnection Delays in Multilayer Integrated Circuits, Active Interconnections.

Crosstalk Analysis: Lumped-Capacitance Approximation, Coupled Multiconductor MIS Microstrip line Model of Single-Level Interconnections, Frequency-Domain Modal Analysis of Single-Level Interconnections. ■

Module-5

Crosstalk Analysis: Transmission Line Analysis of Parallel Multilevel Interconnections,Analysis of Crossing Interconnections,Compact Expressions for Crosstalk Analysis,Multiconductor Buses in GaAs High-Speed Logic Circuits.

Electromigration-Induced Failure Analysis: Electromigration in VLSI Interconnection Metallizations: Overview.■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	High-Speed VLSI Interconnections	Ashok K. Goel	Wiley	2007

(Group -4): 20EMS252 Robust Control Theory

Exam Hours: 3 hours | **Exam Marks(Maximum):100**

Module-1

Introduction: Systems and Control, Modern Control Theory, Stability, Optimal Control, Optimal Control Approach, Kharitonov Approach, H_∞ and H_2 Control, Applications.
Optimal Control and Optimal Observers: Optimal Control Problem, Principle of Optimality, Hamilton–Jacobi–Bellman Equation, Linear Quadratic Regulator Problem, Kalman Filter. ■

Module-2

Robust Control of Linear Systems: Introduction, Matched Uncertainty, Unmatched Uncertainty, Uncertainty in the Input Matrix.■

Module-3

Robust Control of Nonlinear Systems: Introduction, Matched Uncertainty, Unmatched Uncertainty, Uncertainty in the Input Matrix.
Kharitonov Approach: Introduction, Preliminary Theorems, Kharitonov Theorem, Control Design Using Kharitonov Theorem. ■

Module-4

H_∞ and H_2 Control: Introduction, Function Space, Computation of H_∞ and H_2 Norms, Robust Control Problem as H_∞ and H_2 Control Problem, H_∞ / H_2 Control Synthesis. ■

Module-5

Robust Active Damping: Introduction, Problem Formulation, Robust Active Damping Design, Active Vehicle Suspension System.
Robust Control of Manipulators: Robot Dynamics, Problem Formulation, Robust Control Design, Simulations.
Aircraft Hovering Control: Modelling and Problem Formulation, Control Design for Jet-borne Hovering, Simulation.■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Robust Control Design; An Optimal Control Approach	Feng Lin	Wiley	2007

(Group -4): 20EMS251 Reset Control Systems

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Introduction: Motivation of reset control, Basic concepts of RCSs, Fundamental theory of traditional reset design. ■

Module-2

Describing function analysis of reset systems: Sinusoid input response, Describing function, Application to HDD systems. ■

Module-3

Stability of reset control systems: Preliminaries, Quadratic stability, Stability of RCSs with time-delay, Reset times-dependent stability, Passivity of RCSs.■

Module-4

Robust stability of reset control systems: Definitions and assumptions, Quadratic stability, Affine quadratic stability, Robust stability of RCS with time-delay, Examples.
RCSs with discrete-time reset conditions: Preliminaries and problem setting, Stability analysis, A heuristic design method, Application to track-seeking control of HDD systems. ■

Module-5

Reset control systems with fixed reset instants: Stability analysis, Moving horizon optimization, Optimal reset law design, Application to HDD systems, Application to PZT-positioning stage.
Reset control systems with conic jump sets: Basic idea, L 2 -gain analysis. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Analysis and Design of Reset Control Systems	Yuqian Guo et al	IET	2015

(Group -4): 20EMS321 Industrial control: Software and Routines

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Microprocessor Boot Code: Code Structures, Single-Processor Boot Sequences, Multiprocessor Boot Sequences. **Real-Time Operating Systems:** Introduction, Task Controls, Input /Output Device Drivers. ■

Module-2

Real-Time Operating Systems (continued): Interrupts, Memory Management, Event Brokers, Message Queue, Semaphores, Timer. ■

Module-3

Distributed Operating Systems: Multiprocessor Operating Systems, Multicomputer Operating Systems, Distributed and Parallel Facilities. ■

Module-4

Industrial Control System Operation Routines: Self-Test Routines, Install and Configure Routines, Diagnosis Routines, Calibration Routines. ■

Module-5

Industrial Control System Simulation Routines: Modelling and Identification, Simulation and Control, Software and Simulator. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Advanced Industrial Control Technology	Peng Zhang	Elsevier	2010

(Group -5): 20EPS242 Power System Harmonics

Exam Hours: 3 hours | **Exam Marks(Maximum):100**

Module-1

Fundamentals of Harmonics: Introduction, Examples of harmonic waveforms, characteristics of harmonics in power systems, measurement of harmonic distortion, power in passive elements, calculation of passive elements, resonance, capacitor banks and reactive power supply, capacitor banks and power factor correction, bus voltage rise and resonance, harmonics in transformers.

Harmonics in Power system: Introduction, sources of harmonics, transformers, rotating machines, fluorescent lights, static var compensators, cycloconverters. Single phase controlled rectifiers, three phase converters. ■

Module-2

Effects of Harmonic Distortion on Power System: Introduction, thermal losses in a harmonic environment, harmonic effects on power system equipment, capacitor banks, transformers, rotating machines, protection, communication and electronic equipment.

Mitigation of Power system Harmonics: Introduction, harmonic filters, power converters, transformers, rotating machines, capacitor banks, harmonic filter design, active filters. ■

Module-3

Limits of Harmonic Distortion: Introduction, voltage harmonic distortion limits, current harmonic distortion limits.

Harmonic studies – Modelling of System Components: Introduction, impedance in the presence of harmonics, skin effect, modelling of the high voltage grid, generator modelling, modelling of shunt capacitor banks, series capacitor banks, load models, induction motor modelling.

Transformer Modelling: Introduction, modelling of two winding transformers, phase sequence admittance matrices, transmission of voltage and current across two winding transformers, transmission matrices and phase admittance matrix, modelling of three and four winding transformers.■

Module-4

Modelling of Transmission lines/Cables: Introduction, skin effect, modelling of power lines, Line’s series impedance, mutual coupling between conductors, mutually coupled lines, line’s shunt capacitance, surge impedance and velocity of propagation, line’s series impedance and shunt capacitance – single phase equivalents, the transmission (ABCD) matrix, the admittance matrix, conversion between the transmission and admittance matrices, the nominal pi model – single phase equivalent, the equivalent pi model – voltage and current the line, line losses, the equivalent pi model – single phase equivalent, variations in the network’s short circuit capacity, examples – the nominal and equivalent models. ■

Module-5

Power System Harmonic Studies: Introduction, harmonic analysis using a computer program, harmonic analysis using spread sheet, harmonic distortion limits, harmonic filter rating, and practical considerations. Harmonic study of simple system, 300 -22 kV power system and low voltage system. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text/Reference Books

1	Power System Harmonics	George J Wakileh	Springer	Reprint, 2014
2	Power System Harmonic Analysis	Jos Arrillaga et al	Wiley	Reprint, 2014
3	Power System Harmonic	J. Arrillaga, N.R. Watson	Wiley	2^{nd} Edition, 2003
4	Harmonics and Power Systems	Francisco C. DE LA Rosa	CRC Press	1^{st} Edition, 2006

(Group -5): 20EPS252 Power System Voltage Stability

Exam Hours: 3 hours | **Exam Marks(Maximum):100**

Module-1

Electric Power Systems: Introduction to Power System Analysis and Operation, Active and Reactive Power Transmission, Difficulties with Reactive Power Transmission, Short Circuit Capacity, Short Circuit Ratio, and Voltage, Regulation.
Voltage Stability: Voltage Stability, Voltage Collapse, and Voltage Security, Time Frames for Voltage Instability, Mechanisms, Relation of Voltage Stability to Rotor Angle Stability, Voltage Instability in Mature Power Systems, P-V and V – Q Curves, Graphical Explanation of Longer-Term Voltage Stability.
Reactive Power Compensation and Control: Transmission System Characteristics, Series Capacitors, Shunt Capacitor Banks and Shunt Reactors, Static Var Systems, Comparisons between Series and Shunt Compensation, Synchronous Condensers, Transmission Network LTC Transformers.■

Module-2

Power System Loads: Overview of Subtransmission and Distribution Networks, Static and Dynamic Characteristics of Load Components, Reactive Compensation of Loads, LTC Transformers and Distribution Voltage Regulators. ■

Module-3

Generation Characteristics: Generator Reactive Power Capability, Generator Control and Protection, System Response to Power Impacts, Power Plant Response, Automatic Generation Control (AGC). ■

Module-4

Voltage Stability of a Large System: System Description, Load Modelling and Testing, Power Flow Analysis, Dynamic Performance Including Undervoltage Load Shedding, Automatic Control of Mechanically Switched Capacitors. ■

Module-5

Voltage Stability with HVDC Links: Basic Equations for HVDC, HVDC Operation, Voltage Collapse, Voltage Stability Concepts Based on Short Circuit Ratio, Power System Dynamic Performance.
Power System Planning and Operating Guidelines: Solutions: Generation System, Solutions: Transmission System, Distribution and Load Systems, Power System Operation, Voltage Stability Challenge. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text/Reference Books

1	Power System Voltage Stability	Carson W. Taylor	McGraw-Hill	1994
2	Voltage Stability of Electric Power Systems	Van Cutsem, Thierry et al	Springer	1998
3	Power System Stability and Control	P.Kundur	McGraw-Hill	1994

(Group -5): 20EPS241 Insulators for Power System	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Insulators: Definition, Insulators for Transmission System, Elements of an Insulator. Terminology for Insulators: Classification of Insulators, Insulator Construction, Electrical Stresses on Insulators, Environmental Stresses on Insulators, Mechanical Stresses. ■ (Refer to chapter 01 of JST Looms and chapter 02 of Masoud Farzaneh)

Module-2

Design and Manufacturing of Insulators: Porcelain insulators, Glass Insulators, Nonceramic Insulators.

Testing Standards for Insulators: Need for Standards, Standards Producing Organizations, Insulator Standards, Classification of Porcelain /Glass Insulator Tests, Brief Description and philosophy of various Tests for /Cap and Pin Porcelain/Glass Insulators, Summary of Standards for Porcelain/Glass Insulators, Standards for Nonceramic (Composite) Insulators, Classification of Tests, Philosophy and Brief Description, Summary of Standards for Non-ceramic Insulators. ■ (Refer to chapters 02 and 03 of Ravi S Gorur)

Module-3

Selection of Insulators: Introduction, Cost and Weight, National Electricity Safety Code (NESC), Basic Lightning Impulse Insulation Level (BIL), Contaminating Performance, Experience with Silicone Rubber Insulators in Salt Areas of Florida, Compaction, Grading Rings for Nonceramic Insulators, Maintenance Inspections.

Physics of contamination: Electrically significant deposits, Contaminating processes, Purging processes, Equilibrium deposit, Assessment of required insulation: Severity measurement.

Physics of Pollution flashover: Flash paradox, Stages of the flashover process, Models and empirical theories of complete flashover. ■ (Refer to chapters 04 of Ravi S Gorur, chapters 10 and 11 of JST Looms)

Module-4

Icing Flashovers: Terminology for Ice, Ice Morphology, Electrical Characteristics of Ice, Ice Flashover Experience, Ice Flashover Processes, Icing Test Methods, Ice Flashover Test Results. ■
(Refer to chapter 07 of Masoud Farzaneh)

Module-5

Testing of Insulators: Classes of test, Natural pollution testing: Background, Artificial pollution testing, Comparison of artificial-pollution tests, Source impedance: Effect on test results, Principles of mechanical testing.

Conclusions from pollution test on insulators: Scope of chapter, Deterioration: test results, validity of testing of insulators.

Insulator of the future: Indicators from known facts, Extrapolation from current practices.■ (Refer to chapters 12, 13 and 17 of JST Looms)

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks

1	Insulators for High Voltages	J.S.T. Looms	Institution of Engineering and Technology	2006
2	Outdoor Insulators	Ravi S Gorur	Ravi S Gorur, Inc. 16215 S. 36th Street, Phoenix, Arizona 85044	1999
3	Insulators for Icing and Polluted Environments	Masoud Farzaneh et al	Wiley	2009

(Group -5): 20EPS22 Switching in Power Systems

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Switching in Power Systems: Introduction, Organization of this Book, Power-System Analysis, Purpose of Switching, The Switching Arc, Transient Recovery Voltage (TRV), Switching Devices, Classification of Circuit-Breakers.
Faults in Power Systems: Introduction, Asymmetrical Current, Short-Circuit Current Impact on System and Components, Fault Statistics.
Fault-Current Breaking and Making: Introduction, Fault-Current Interruption, Terminal Faults, Transformer - Limited Faults, Reactor-Limited Faults. ■

Module-2

Fault-Current Breaking and Making (continued): Faults on Overhead Lines, Out-of-Phase Switching, Fault-Current Making.
Load Switching: Normal-Load Switching, Capacitive-Load Switching, Inductive-Load Switching. ■

Module-3

Calculation of Switching Transients: Analytical Calculation, Numerical Simulation of Transients.
Current Interruption in Gaseous Media: Introduction, Air as an Interrupting Medium, Oil as an nterrupting Medium, Sulphur Hexafluoride (SF6) as an Interrupting Medium, SF6 – N2 Mixtures. ■

Module-4

Gas Circuit-Breakers: Oil Circuit-Breakers, Air Circuit-Breakers, SF6 Circuit-Breakers.
Current Interruption in Vacuum: Introduction, Vacuum as an Interruption Environment, Vacuum Arcs.
Vacuum Circuit-Breakers: General Features of Vacuum Interrupters, Contact Material for Vacuum Switchgear, Reliability of Vacuum Switchgear, Electrical Lifetime, Mechanical Lifetime, Breaking Capacity, Dielectric Withstand Capability, Current Conduction, Vacuum Quality, Vacuum Switchgear for HV Systems.■

Module-5

Special Switching Situations: Generator-Current Breaking, Delayed Current Zero in Transmission Systems, Disconnector Switching, Earthing, Switching Related to Series Capacitor Banks, Switching Leading to Ferro resonance, Fault-Current Interruption Near Shunt Capacitor Banks, Switching in Ultra-High-Voltage (UHV) Systems, High-Voltage AC Cable System Characteristics, Switching in DC Systems, Distributed Generation and Switching Transients, Switching with Non-Mechanical Devices.
Switching Overvoltages and Their Mitigation: Overvoltages, Switching Overvoltages, Switching-Voltage Mitigation, Mitigation by Controlled Switching. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Switching in Electrical Transmission and Distribution Systems	Ren´e Smeets et al	Wiley	2015

(Group -5): 20EPS331 Smart Grid

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

The Smart Grid: Introduction, Smart Grid and Early initiatives, Overview of the technologies required for the Smart Grid.
Data communication: Introduction, Dedicated and shared communication channels, Switching techniques, Communication channels, Layered architecture and protocols.
Communication technologies for the Smart Grid: Introduction, Communication technologies, Standards for information exchange. ■

Module-2

Information security for the Smart Grid: Introduction, Encryption and decryption, Authentication, Digital signatures, Cyber security standards.
Smart metering and demand-side integration: Introduction, Smart metering, Smart meters: An overview of the hardware used, Communications infrastructure and protocols for smart metering, Demand-side integration. ■

Module-3

Distribution automation equipment: Introduction, Substation automation equipment, Faults in the distribution system, Voltage regulation.
Distribution management systems: Introduction, Data sources and associated external systems, Modelling and analysis tools, Applications. ■

Module-4

Transmission system operation: Introduction, Data sources, Energy management systems, Wide area applications, Visualisation techniques.
Power electronic converters: Introduction, Current source converters, Voltage source converters.
Power electronics in the Smart Grid: Introduction, Renewable energy generation, Fault current limiting, Shunt compensation, Series compensation. ■

Module-5

Power electronics for bulk power flows: Introduction, FACTS, HVDC.
Energy storage: Energy storage technologies, Case study 1: Energy storage for wind power, Case study 2: Agent-based control of electrical vehicle battery charging. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Smart Grid Technology and Applications	Janaka Ekanayake et al	Wiley	2012

(Group -5): 20EPE321 MPPT in Solar Systems

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

PV Modelling: From the Photovoltaic Cell to the Field, The Electrical Characteristic of a PV Module, The Double-Diode and Single-Diode Models, From Data Sheet Values to Model Parameters, Example: PV Module Equivalent Circuit Parameters Calculation, The Lambert W Function for Modelling a PV Field, Example.
Maximum Power Point Tracking: The Dynamic Optimization Problem, Fractional Open-Circuit Voltage and Short-Circuit Current, Soft Computing Methods, The Perturb and Observe Approach. ■

Module-2

Maximum Power Point Tracking (continued): Improvements of the P&O Algorithm, Evolution of the Perturbative Method, PV MPPT via Output Parameters, MPPT Efficiency.
MPPT Efficiency: Noise Sources and Methods for Reducing their Effects: Low-Frequency Disturbances in Single-Phase Applications, Instability of the Current-Based MPPT Algorithms, Sliding Mode in PV System, Analysis of the MPPT Performances in a Noisy Environment, Numerical Example. ■

Module-3

Distributed Maximum Power Point Tracking of Photovoltaic Arrays: Limitations of Standard MPPT, A New Approach: Distributed MPPT, DC Analysis of a PV Array with DMPPT, Optimal Operating Range of the DC Inverter Input Voltage. ■

Module-4

Distributed Maximum Power Point Tracking of Photovoltaic Arrays (continued): AC Analysis of a PV Array with DMPPT. ■

Module-5

Design of High-Energy-Efficiency Power Converters for PV MPPT Applications: Introduction, Power, Energy, Efficiency, Energy Harvesting in PV Plant Using DMPPT Power Converters, Losses in Power Converters, Losses in the Synchronous FET Switching Cells, Conduction Losses, Switching Losses. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Power electronics and Control Techniques for Maximum energy harvesting in Photovoltaic systems	Nicola Femia et al	CRC Press	2013

(Group -5): 20EPE331 Advanced Control Systems

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Digital Control: Control System Terminology, Need of Digital control, Configurations of the Basic Digital Control Scheme, Principle of Signal Conversion, Basic Discrete – Time Signals, Time Domain Models for Discrete – Time Systems, The z – Transform, Transfer Function Models, Frequency Response, Stability on the z – Plane and Jury Stability Criterion, Sample and Hold Systems, Sampled Spectra and Aliasing, Reconstruction of Analog Signals, Practical Aspects of the choice of Sampling Rate, Principle of Discretization. ■

Module-2

Models of Digital Control Devices and Systems: Introduction, z – Domain Description of Sampled Continuous – time Plants, z – Domain Description of Samples with Dead – Time, Implementation of Digital Controllers, Tunable PID Controllers, Digital Temperature and Position Control Systems, Stepping Motors and their Control. ■

Module-3

State Variable Analysis of Digital Control Systems: Introduction, State Description of Digital Processors, State Description of Sampled continuous – Time Plants, State Description of Systems with Dead Time, Solution of State Difference Equations, Controllability and Observability, Multivariable Systems.

Pole Placement Design and State Observers: Introduction, Stability Improvement by State Feedback, Necessary and sufficient Conditions for Arbitrary Pole – Placement, State Regulator Design, Design of State Observers, Compensator Design by the Separation Principle, Servo Design – Introduction of the reference Input by Feedforward Control, State Feedback with Integral Control, Digital Control Systems with State Feedback, Deadbeat control by State Feedback and Deadbeat Observers. ■

Module-4

Quadratic Optimal Control: Introduction, The Concept of Lyapunov Stability, Lyapunov Functions for Linear Systems, Parameter Optimization and Optimal Control Problems, Quadratic Performance Index, Control Configurations, Optimal State Regulator, Optimal Digital Control Systems, Constrained State Feedback Control. ■

Module-5

Nonlinear System Analysis: Introduction, Common nonlinear System Behaviours, Common nonlinearities in Control Systems, Describing Function Fundamentals, Describing Function of Common nonlinearities, Stability Analysis by the Describing Function Method, Concept of Phase Plane Analysis, Construction of Phase Portraits, System Analysis on the Phase Plane, Simple Variable Structure Systems, Lyapunov Stability Definitions, Lyapunov Stability Theorems, Lyapunov Functions for Nonlinear Systems. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

1	Digital Control and State Variable Methods (Conventional and Intelligent Control	M Gopal	Mc Graw Hill	3rd Edition, 2008
2	Discrete – Time Control Systems	Katsuhiko Ogata	Pearson	2nd Edition, 2015
3	Digital Control Systems	Benjamin C Kuo	Oxford University Press	2nd Edition, 2007
4	Control System Engineering	I.J. Nagrath M.Gopal	New Age International	5th Edition, 2007

(Group -5): 20ECD241 Special Electrical Machines

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Stepper Motor: Introduction, Variable Reluctance Stepper Motor, Permanent Magnet Stepper Motor, Hybrid Stepper Motor, Other Types of Stepper Motor, Windings in Stepper Motors, Torque Equation, Characteristics of Stepper Motor, Open – loop Control of Stepper Motor, Closed – loop Control of Stepper Motor, Microprocessor – Based Control of Stepper Motor, Applications of Stepper Motor. ■

Module-2

Switched Reluctance Motor (SRM): Construction, Principle of Working, Basics of SRM Analysis, Constraints on Pole Arc and Tooth Arc, Torque Equation and Characteristics, Power Converter Circuits, Control of SRM, Rotor Position Sensors, Current Regulators, Microprocessor – Based Control of SRM, Sensorless Control of SRM.
Permanent Magnet DC Motor and Brushless Permanent Magnet DC Motor: Permanent Magnet DC (PMDC) motor, Brushless Permanent Magnet DC (BLDC) Motors. ■

Module-3

Permanent Magnet Synchronous Motor (PMSM): Construction, Principle of Operation, EMF Equation, Torque Equation, Phasor Diagram, Circle Diagram, Comparison of Conventional and PMSM, Control of PMSM, Applications.
Synchronous Reluctance Motor (SyRM): Constructional of SyRM, Working, Phasor Diagram and Torque Equation, Control of SyRM, Advantages and Applications. ■

Module-4

Single Phase Special Electrical Machines: AC series Motor, Repulsion Motor, Hysteresis Motor, Single Phase Reluctance Motor, Universal Motor.
Servo Motors: DC Servo Motors, AC Servo Motors. ■

Module-5

Linear Electric Machines: Linear Induction Motor, Linear Synchronous Motor, DC Linear Motor, Linear Reluctance Motor, Linear Levitation Machines.
Permanent Magnet Axial Flux (PMAF) Machines: Comparison of Permanent Radial and Axial Flux Machines, Construction of PMAF Machines, Armature Windings, torque and EMF Equations of PMAF, Phasor Diagram, Output Equation, Pulsating Torque And its Minimisation, Control and Applications of PMAF. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

1	Special Electrical Machines	E.G. Janardanan	PHI	1st Edition 2014.
2	Special Electrical Machines	K Venkataratham	University Press	2009
3	Brushless Permanent Magnet and Reluctance Motor Drives	T J E Miller	Clerendon Press, Oxford	1989
4	Permanent Magnet and Brushless DC Motors	Kenjo T and Nagamori S	Clerendon Press, Oxford	1985
5	Stepping Motors and their Microprocessor Control	KenjoT	Clerendon Press Oxford	1984
6	Switched Reluctance Motor Drives Modelling, Simulation Design and Applications	Krishan R	CRC	2001

(Group -5): 20ECD22 DSP Applications to Drives

Exam Hours: 3 hours | **Exam Marks(Maximum):100**

Module-1

Introduction to the TMSLF2407 DSP Controller: Introduction, Brief Introduction to Peripherals, Types of Physical Memory, Software Tools.

C2xx DSP CPU and Instruction Set: Introduction to the C2xx DSP Core and Code Generation, The Components of the C2xx DSP Core, Mapping External Devices to the C2xx Core and the Peripheral Interface, System Configuration Registers, Memory, Memory Addressing Modes, Assembly Programming Using the C2xx DSP Instruction Set. ■

Module-2

General Purpose Input /Output (GPIO) Functionality: Pin Multiplexing (MUX) and General Purpose I/O Overview, Multiplexing and General Purpose I/O Control Registers, Using the General Purpose I/O Ports, General Purpose I/O Exercise.

Interrupts on the TMS320LF2407: Introduction to Interrupts, Interrupt Hierarchy, Interrupt Control Registers, Initializing and Servicing Interrupts in Software, Interrupt Usage Exercise.

The Analog-to-Digital Converter (ADC): ADC Overview, Operation of the ADC, Analog to Digital Converter Usage Exercise. ■

Module-3

The Event Managers (EVA, EVB): Overview of the Event Manager (EV), Event Manager Interrupts, General Purpose (GP) Timers, Compare Units, Capture Units and Quadrature Encoded Pulse (QEP) Circuitry, General Event Manager Information, Exercise: PWM Signal Generation. ■

Module-4

DSP-Based Implementation of DC-DC Buck-Boost Converters: Introduction, Converter Structure, Continuous Conduction Mode, Discontinuous Conduction Mode, Connecting the DSP to the Buck-Boost Converter, Controlling the Buck-Boost Converter, Main Assembly Section Code Description, Interrupt Service Routine, The Regulation Code Sequences, Results.

DSP-Based Control of Stepper Motors: Introduction, The Principle of Hybrid Stepper Motor, The Basic Operation, The Stepper Motor Drive System, The Implementation of Stepper Motor Control System Using the LF2407 DSP, The Subroutine of Speed Control Module.

DSP-Based Control of Permanent Magnet Brushless DC Machines: Introduction, Principles of the BLDC Motor, Torque Generation, BLDC Motor Control System, Implementation of the BLDC Motor Control System Using the LF2407.

Clarke's and Park's Transformations: Introduction, Clarke's Transformation, Park's Transformation, Transformations between Reference Frames, Field Oriented Control (FOC) Transformations, Implementing Clarke's and Park's Transformations on the LF240X. ■

Module-5

Space Vector Pulse Width Modulation: Introduction, Principle of Constant V/Hz Control for Induction Motors, Space Vector PWM Technique, DSP Implementation.

DSP-Based Control of Permanent Magnet Synchronous Machines: Introduction, The Principle of the PMSM, PMSM Control System, Implementation of the PMSM System Using the LF2407.

DSP-Based Vector Control of Induction Motors: Introduction, Three-Phase Induction Motor Basic Theory, Model of the Three-Phase Induction Motor in Simulink, Reference Frame Theory, Induction Motor Model in the Arbitrary q-d-0 Reference Frame, Field Oriented Control, DC Machine Torque Control, Field Oriented Control, Direct and Indirect Approaches, Simulation Results for the Induction Motor Control System, Induction Motor Speed Control System, System Components, Implementation of Field-Oriented Speed Control of Induction Motor, Experimental Results. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	DSP-Based Electromechanical Motion Control	Hamid A. Toliyat	CRC Press	2004

(Group -5): 20ECD333 Sneak Circuits in Converters

Exam Hours: 3 hours | **Exam Marks(Maximum):100**

Module-1

Sneak Circuit and Power Electronic Systems: Reliability of Power Electronic Systems, Sneak Circuit, Sneak Circuit Analysis, Power Electronic System and Sneak Circuit Analysis.
Sneak Circuits of Resonant Switched Capacitor Converters: Introduction, Sneak Circuits of Basic RSC Converter, Sneak Circuits of High-Order RSC Converter. ■

Module-2

Sneak Circuits of DC-DC Converters: Introduction, Buck Converter, Boost Converter, Buck-Boost Converter, Sneak Circuit Conditions of Buck, Boost, and Buck-Boost Converters, Cúk Converter, Sepic Converter, Zeta Converter, Sneak Circuit Conditions of Cúk, Sepic, and Zeta Converters. ■

Module-3

Sneak Circuits of Soft-Switching Converters: Introduction, Sneak Circuits of Full-Bridge ZVS PWM Converter, Sneak Circuits of Buck ZVS Multi-Resonant Converter, Sneak Circuits of Buck ZVT PWM Converter.
Sneak Circuits of other Power Electronic Converters: Introduction, Sneak Circuits of Z-Source Inverter, Sneak Circuits of Synchronous DC-DC Converters. ■

Module-4

Sneak Circuit Path Analysis Method for Power Electronic Converters: 1 Introduction, Basic Concepts, Sneak Circuit Path Analysis Based on Adjacency Matrix, Sneak Circuit Path Analysis Based on Connection Matrix, Sneak Circuit Path Analysis Based on Switching Boolean Matrix, Comparison of Three Sneak Circuit Path Analysis Methods.
Sneak Circuit Mode Analysis Method for Power Electronic Converters: Introduction, Mesh Combination Analytical Method, Sneak Operating Unit Analytical Method, Sneak Circuit Operating Mode Analytical Method, Results of Sneak Circuit Mode Analysis Method on Cúk Converter. ■

Module-5

Elimination of Sneak Circuits in Power Electronic Converters: Introduction, Sneak Circuit Elimination for RSC Converters, Sneak Circuit Elimination for Z-Source Inverter, Sneak Circuit Elimination for Buck ZVT PWM Converter.
Application of Sneak Circuits in Power Electronic Converters: Introduction, Improvement of Power Electronic Converter Based on Sneak Circuits, Reconstruction of Power Electronic Converter Based on Sneak Circuits, New Functions of Power Electronic Converter Based on Sneak Circuits, Fault Analysis of Power Electronic Converter Based on Sneak Circuits. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Sneak Circuits of Power Electronic Converters	Bo Zhang and Dongyuan Qiu	Wiley	2015

(Group -5): 20ESE22 Industrial Energy and Management

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Engineering Aspects of Industrial Energy Management: Introduction to Industrial Energy Systems.
Industrial Steam System: System Performance Definition, Principles of Performance Analysis, Analysis of Boiler Performance, Factors Influencing Boiler Performance, Opportunities for Boiler Performance Improvement, Software for Boiler Performance Analysis, Boiler Performance Monitoring, Steam Distribution and Condensate Return System, Condensate Return System, Environmental Impacts. ■

Module-2

Industrial Electric Power System: Introduction,Description of Industrial Electric Power Systems, Basic Terms, Tariff System, Main Components of Industrial Electric Power Systems, Performance Assessment of Industrial Electric Power Systems, Performance Improvement Opportunities, Maintenance Considerations, Performance Monitoring, Environmental Impacts. ■

Module-3

Compressed Air System: System Description, Performance Analysis, Performance Improvement Opportunities, Performance Monitoring, Example: Detailed Energy Audit of Compressed Air System, Example: Comparison of Load/Unload and Pump-up Tests.■

Module-4

Refrigeration System: Description of System, Performance Definitions, Performance Analysis, Performance Improvement Opportunities, Performance Monitoring, Example: Improvement of Chilled Water System Operation. ■

Module-5

Industrial Cogeneration: System Description, Principles of Operation, Types of Industrial Cogeneration Plants, Operational Modes of Cogeneration Systems, Performance Definition, Factors Influencing Performance, Economic Aspects of Cogeneration as a Performance Improvement Measure, Performance Assessment, Performance Monitoring and Improvement, Environmental Impacts, Case Study: Drying Kiln (Gas Turbine Operation Philosophy Improvement). ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Applied Industrial Energy and Environmental Management	Zoran K. Morvay et al	Wiley	2088

(Group -5): 20ESE254 Intelligent Energy Demand Forecasting	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Introduction: Traditional Approaches for Electric Load Forecasting, Artificial Intelligent Technology for Electric Load Forecasting, Support Vector Regression for Electric Load Forecasting, Feasible Approaches to Improve the Forecasting Accuracy Performance.
Modeling for Energy Demand Forecasting: Autoregressive Integrated Moving Average Model, Seasonal Autoregressive Integrated Moving Average Model,Holt–Winters Model, Seasonal Holt–Winters (SHW) Model, General Regression Neural Network Model, Back-Propagation Neural Networks Model, Support Vector Regression Model. ■

Module-2

Evolutionary Algorithms in SVR's Parameter Determination: Data Set and Forecasting Comparison Statistical Tests, Modeling and Forecasting Results of Alternative Models, Genetic Algorithm in SVR's Parameter Determination, Simulated Annealing Algorithm in SVR's Parameter Determination, Hybrid GA with SA in SVR's Parameter Determination, Particle Swarm Optimization Algorithm in SVR's Parameter Determination. ■

Module-3

Evolutionary Algorithms in SVR's Parameter Determination: Continuous Ant Colony Optimization Algorithm in SVR's Parameter Determination, Artificial Bee Colony Algorithm in SVR's Parameter Determination, Immune Algorithm in SVR's Parameter Determination.
Chaos/Cloud Theories to Avoid Trapping into Local Optimum (continued): Brief Introductions of Chaotic Sequence and Cloud Model, Chaotic Genetic Algorithm (CGA) in SVR's Parameters Determination, Chaotic Simulated Annealing Algorithm in SVR's Parameters Determination. ■

Module-4

Chaos/Cloud Theories to Avoid Trapping into Local Optimum (continued): Chaotic Cloud Simulated Annealing Algorithm in SVR's Parameters Determination, Chaotic GASA (CGASA) Algorithm in SVR's Parameters Determination, Chaotic PSO (CPSO) Algorithm in SVR's Parameters Determination, Chaotic Ant Swarm Optimization Algorithm in SVR's Parameters Determination, Chaotic Artificial Bee Colony Algorithm in SVR's Parameters Determination, Chaotic Immune Algorithm in SVR's Parameters Determination. ■

Module-5

Recurrent/Seasonal Mechanism to Improve the Accurate Level of Forecasting: Combined Mechanisms, Seasonal ARIMA Model and Seasonal HW (SHW) Model, Seasonal Mechanism in SVRCGA Model and Forecasting Results, Seasonal Mechanism in SVRCSA Model and Forecasting Results, Seasonal Mechanism in SVRCCSA Model and Forecasting Results, Seasonal Mechanism in SVRCGASA Model and Forecasting Results, Seasonal Mechanism in SVRCPSO Model and Forecasting Results, Seasonal Mechanism in SVRCAS Model and Forecasting Results, Seasonal Mechanism in SVRCABC Model and Forecasting Results, Recurrent and Seasonal Mechanisms in SVRCABC Model and Forecasting Results, Seasonal Mechanism in SVRCIA Model and Forecasting Results. ■

Question paper pattern:
The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 20 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module. ■

Textbook

1. Intelligent Energy Demand Forecasting, Wei-Chiang Hong, Springer-Verlag, 2013.

(Group -5): 20EMS23 CAD Tools For VLSI Design

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

VLSI Physical Design Automation: VLSI Design Cycle, New Trends in VLSI Design Cycle, Physical Design Cycle, New Trends in Physical Design Cycle, Design Styles, System Packaging Styles.
Design and Fabrication of VLSI Devices: Fabrication Materials, Transistor Fundamentals, Fabrication of VLSI Circuits, Design Rules, Layout of Basic Devices. ■

Module-2

Data Structures and Basic Algorithms: Basic Terminology, Complexity Issues and NP-hardness, Basic Algorithms, Basic Data Structures, Graph Algorithms for Physical design.■

Module-3

Partitioning: Problem Formulation, Classification of Partitioning Algorithms, Group Migration Algorithms, Simulated Annealing and Evolution, Other Partitioning Algorithms, Performance Driven Partitioning.
Floorplanning and Pin Assignment: Floorplanning, Chip planning, Pin Assignment, Integrated Approach. ■

Module-4

Placement: Problem Formulation, Classification of Placement Algorithms, Simulation Based Placement Algorithms, Partitioning Based Placement Algorithms, Other Placement Algorithms, Performance Driven Placement.
Global Routing: Problem Formulation, Classification of Global Routing Algorithms, Maze Routing Algorithms, Line-Probe Algorithms, Shortest Path Based Algorithms, Steiner Tree based Algorithms, Integer Programming Based Approach, Performance Driven Routing. ■

Module-5

Detailed Routing: Problem Formulation, Classification of Routing Algorithms, Single-Layer Routing Algorithms, Two-Layer Channel Routing Algorithms, Three-Layer Channel Routing Algorithms, Multi-Layer Channel Routing Algorithms, Switchbox Routing Algorithms. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Algorithms for VLSI Physical Design Automation	Naveed A. Sherwani	Kluwer Academic Publishers	3rd Edition, 2002

(Group -5): 20EMS253 Digital System Design with VHDL

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Introduction: Modern digital design, CMOS technology, Programmable logic, Electrical properties.
Combinational logic design: Boolean algebra, Logic gates, Combinational logic design, Timing, Number codes.
Combinational logic using VHDL gate models: Entities and architectures, Identifiers, spaces and comments, Netlists, Signal assignments, Generics, Constant and open ports, Testbenches, Configurations. ■

Module-2

Combinational building blocks: Three-state buffers, Decoders, Multiplexers, Priority encoder, Adders, Parity checker, Testbenches for combinational blocks.
Synchronous sequential design: Synchronous sequential systems, Models of synchronous sequential systems, Algorithmic state machines, Synthesis from ASM charts, State machines in VHDL, VHDL testbenches for state machines. ■

Module-3

VHDL models of sequential logic blocks: Latches, Flip-flops, JK and T flip-flops, Registers and shift registers, Counters, Memory, Sequential multiplier, Testbenches for sequential building blocks.
Complex sequential systems: Linked state machines, Datapath /controller partitioning, Instructions, A simple microprocessor, VHDL model of a simple microprocessor. ■

Module-4

VHDL simulation: Event-driven simulation, Simulation of VHDL models, Simulation modelling issues, File operations.
VHDL synthesis: RTL synthesis, Constraints, Synthesis for FPGAs, Behavioural synthesis, Verifying synthesis results.
Testing digital systems: The need for testing, Fault models, Fault-oriented test pattern generation, Fault simulation, Fault simulation in VHDL. ■

Module-5

Design for testability: Ad hoc testability improvements, Structured design for test, Built-in self-test, Boundary scan (IEEE 1149.1).
Asynchronous sequential design: Asynchronous circuits, Analysis of asynchronous circuits, Design of asynchronous sequential circuits, Asynchronous state machines, Setup and hold times and metastability.
Interfacing with the analogue world: Digital to analogue converters, Analogue to digital converters, VHDL-AMS, Phase-locked loops, VHDL-AMS simulators. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Digital System Design with VHDL	Mark Zwoli´nski	Pearson	2^{nd} Edition, 2004

(Group -6): 20EPS251 Linear and Nonlinear Optimization

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Optimization: Introduction, historical development, engineering applications of optimization, statement of an optimization problem, design vector, design constraints, constraint surface, objective function, objective function surfaces, classification of optimization problems based on existence of constraints, nature of the design variables, physical structure of the problem, nature of the equations involved, nonlinear and linear programming problem(NLP and LPP), permissible values of the design variables, deterministic nature of the functions, number of objective functions, optimization techniques. ■

Module-2

Classification of Optimization Problems: Introduction, single variable optimization, multivariable optimization with no constraints, semi-definite case, saddle point, multivariable optimization with equality constraints, solution by direct substitution, by the method of constrained variation and by the method of Lagrange multipliers, multivariable optimization with inequality constraints, Kuhn-Tucker conditions, constraint qualification, Convex programming problem. ■

Module-3

Linear Programming-I: Introduction, applications of linear programming, standard form of a LPP, geometry of LPP, definitions and theorems, solution of a system of linear simultaneous equations, pivotal reduction of a general system of equations, motivation of the simplex method, simplex algorithm, identifying an optimal point, improving a non-optimal basic feasible solution, two phases of the simplex method. ■

Module-4

Linear Programming-II: Revised simplex method, duality in linear programming; symmetric and primal-dual relations, primal-dual relations when the primal is in standard form, duality theorems, dual simplex method, decomposition principle, sensitivity or post- optimality analysis, changes in right-hand-side constants b_i, changes in the cost coefficients C_j, addition of new variables, changes in the constraint coefficients a_{ij}, addition of constraints. Transportation problem, Karmarkar's method, statement of the problem, conversion of an LPP into required form, algorithm, quadratic programming. ■

Module-5

Non-Linear Programming - One Dimensional Minimization Methods: Introduction, Unimodal function, Unrestricted search with fixed step size and accelerated step size, exhaustive search, dichotomous search, interval halving method, Fibonacci method, golden section method, comparison of elimination methods, interpolation methods, quadratic and cubic, direct root methods, Newton, Quasi-Newton and Secant methods, practical considerations. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

1	Engineering Optimization	Singiresu S Rao (S S Rao)	Wiley	1996
2	Applied Nonlinear Programming	David Mautner Himmelblau	Mc Graw Hill	1972

(Group -6): 20EPS23 Facts Controllers	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**

Module-1

Control Mechanism of Transmission System: Background, Electrical Transmission Networks, Conventional Control Mechanisms, Flexible ac Transmission Systems (FACTS), Emerging Transmission Networks.
Reactive-Power Control in Electrical Power Transmission Systems: Reactive Power, Uncompensated Transmission Lines, Passive Compensation.
Principles of Conventional Reactive-Power Compensators: Introduction, Synchronous Condensers, The Saturated Reactor (SR), The Thyristor-Controlled Reactor (TCR), The Thyristor-Controlled Transformer (TCT). ■

Module-2

Principles of Conventional Reactive-Power Compensators (continued): The Fixed Capacitor–Thyristor-Controlled Reactor (FC–TCR), The Mechanically Switched Capacitor–Thyristor-Controlled Reactor (MSC–TCR), The Thyristor-Switched Capacitor (TSC), The Thyristor-Switched Capacitor–Thyristor-Controlled Reactor (TSC–TCR), A Comparison of Different SVCs.
SVC Voltage Control: Introduction Voltage Control. ■

Module-3

SVC Voltage Control (continued): Effect of Network Resonances on the Controller Response, The 2nd Harmonic Interaction between the SVC and ac Network, Application of the SVC to Series-Compensated ac Systems, 3rd Harmonic Distortion, Voltage-Controller Design Studies. ■

Module-4

SVC Applications: Introduction, Increase in Steady-State Power-Transfer Capacity, Enhancement of Transient Stability, Augmentation of Power-System Damping - Principle of the SVC Auxiliary Control, Torque Contributions of SVC Controllers, Effect of the Power System, Effect of the SVC, SVC Mitigation of Subsynchronous Resonance (SSR) - Principle of SVC Control, Configuration and Design of the SVC Controller, Rating of an SVC, Prevention of Voltage Instability- Principles of SVC Control- A Case Study, Configuration and Design of the SVC Controller, Rating of an SVC.
The Thyristor-Controlled Series Capacitor (TCSC): Series Compensation, The TCSC Controller, Operation of the TCSC, The TSSC, Analysis of the TCSC, Capability Characteristics, Harmonic Performance, Losses, Response of the TCSC, Modelling of the TCSC. ■

Module-5

TCSC Applications: Introduction, Open-Loop Control, Closed-Loop Control, Improvement of the System-Stability Limit, Enhancement of System Damping, Subsynchronous Resonance (SSR) Mitigation, Voltage-Collapse Prevention.
VSC based FACTS Controllers: Introduction, The STATCOM, The SSSC, The UPFC, Comparative Evaluation of Different FACTS Controllers. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

1	Thyristor-Based FACTs Controllers for Electrical Transmission Systems	R. Mohan Mathur Rajiv K. Varma	Wiley	2002
2	Understanding FACTS: concepts and technology of flexible AC Transmission systems	Narain G. Hingorani Laszlo Gyugyi.	Wiley	2000
3	Facts Controllers in Power Transmission and Distribution	K. R. Padiyar	New Age International	2007

(Group -6): 20EPS253 Power Quality Problems and Mitigation

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Power Quality: Introduction, State of the Art on Power Quality, Classification of Power Quality Problems, Causes of Power Quality Problems, Effects of Power Quality Problems on Users, Classification of Mitigation Techniques for Power Quality Problems.
Power Quality Standards and Monitoring: Introduction, State of the Art on Power Quality Standards and Monitoring, Power Quality Terminologies, Power Quality Definitions, Power Quality Standards, Power Quality Monitoring, Numerical Examples.
Passive Shunt and Series Compensation: Introduction, State of the Art on Passive Shunt and Series Compensators, Classification of Passive Shunt and Series Compensators, Principle of Operation of Passive Shunt and Series Compensators, Analysis and Design of Passive Shunt Compensators, Modelling, Simulation, and Performance of Passive Shunt and Series Compensators, Numerical Examples. ■

Module-2

Active Shunt Compensation: Introduction, State of the Art on DSTATCOMs, Classification of DSTATCOMs, Principle of Operation and Control of DSTATCOMs, Analysis and Design of DSTATCOMs, Modelling, Simulation, and Performance of DSTATCOMs, Numerical Examples. ■

Module-3

Active Series Compensation: Introduction, State of the Art on Active Series Compensators, Classification of Active Series Compensators, Principle of Operation and Control of Active Series Compensators, Analysis and Design of Active Series Compensators, Modelling, Simulation, and Performance of Active Series Compensators, Numerical Examples. ■

Module-4

Unified Power Quality Compensators: Introduction, State of the Art on Unified Power Quality Compensators, Classification of Unified Power Quality Compensators, Principle of Operation and Control of Unified Power Quality Compensators, Analysis and Design of Unified Power Quality Compensators, Modelling, Simulation, and Performance of UPQCs, Numerical Examples (from 6.01 to 6.10). ■

Module-5

Unified Power Quality Compensators (continued): Numerical Examples (from 6.11to 20).
Loads That Cause Power Quality Problems: Introduction, State of the Art on Nonlinear Loads, Classification of Nonlinear Loads, Power Quality Problems Caused by Nonlinear Loads, Analysis of Nonlinear Loads, Modelling, Simulation, and Performance of Nonlinear Loads, Numerical Examples. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Power Quality Problems and Mitigation Techniques	Bhim Singh, Ambrish Chandra, Kamal Al-Haddad	Wiley	2015

(Group -6): 20EPS31 HVDC Power Transmission

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

HVDC Technology: Introduction, Advantages of HVDC Systems, HVDC System Costs, Overview and Organization of HVDC Systems, Review of the HVDC System Reliability, HVDC Characteristics and Economic Aspects.
Power Conversion: Thyristor, 3-Phase Converter, 3-Phase Full Bridge Converter, 12-Pulse Converter. ■

Module-2

Harmonics of HVDC and Removal: Introduction, Determination of Resulting Harmonic Impedance, Active Power Filter.
Control of HVDC Converter and System: Converter Control for an HVDC System, Commutation Failure, HVDC Control and Design. ■

Module-3

Control of HVDC Converter and System (continued): HVDC Control Functions, Reactive Power and Voltage Stability.
Interactions between AC and DC Systems: Definition of Short Circuit Ratio and Effective Short Circuit Ratio, Interaction between HVDC and AC Power System. ■

Module-4

Main Circuit Design: Converter Circuit and Components, Converter Transformer, Cooling System, HVDC Overhead Line, HVDC Earth Electrodes, HVDC Cable, HVDC Telecommunications Current Sensors, HVDC Noise and Vibration. ■

Module-5

Fault Behaviour and Protection of HVDC System: Valve Protection Functions, Protective Action of an HVDC System, Protection by Control Actions, Fault Analysis.
Other Converter Configurations for HVDC Transmission: Introduction, Voltage Source Converter (VSC), CCC and CSCC HVDC System, Multi-Terminal DC Transmission.
Trends for HVDC Applications: Wind Farm Technology, Modern Voltage Source Converter (VSC) HVDC Systems, 800 kV HVDC System. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/Reference Books

1	HVDC Transmission: Power Conversion Applications in Power Systems	Chan-Ki Kim et al	Wiley	2009
2	Direct Current Transmission	E.W. Kimbark	Wiley	1971
3	High Voltage Direct Current Transmission	Arrilaga	IET	2nd Edition, 1998
4	HVDC Transmission	S. Kamakshaiah et al	Mc Graw Hill	2011
5	HVDC and FACTs Controllers; Applications of Static Converters in Power Systems	Vijay K Sood	BSP Books	2013
6	HVDC Power Transmission Systems	K. R. Padiyar	New Age International	2012

(Group -6): 20EPS321 Multi-Terminal DC Grids

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Fundamentals: Introduction, Rationale behind MTDC Grids, Network Architectures of MTDC Grids, Enabling Technologies and Components of MTDC Grids, Control Modes in MTDC Grid, Challenges for MTDC Grids, Configurations of MTDC Converter Stations, Research Initiatives on MTDC Grids.
Voltage-Sourced Converter (VSC): Introduction, Ideal Voltage-Sourced Converter, Practical Voltage-Sourced Converter.■

Module-2

Voltage-Sourced Converter (continued): Control, Simulation.
Modelling, Analysis, and Simulation of AC–MTDC Grids: Introduction, MTDC Grid Model. ■

Module-3

Modelling, Analysis, and Simulation of AC–MTDC Grids (continued): AC Grid Model, AC–MTDC Load flow Analysis, AC–MTDC Grid Model for Nonlinear Dynamic Simulation, Small-signal Stability Analysis of AC–MTDC Grid, Transient Stability Analysis of AC–MTDC Grid. ■

Module-4

Modelling, Analysis, and Simulation of AC–MTDC Grids (continued): Case Study 1: The North Sea Benchmark System, Case Study 2: MTDC Grid Connected to Equivalent AC Systems, Case Study 3: MTDC Grid Connected to Multi-machine AC System.
Autonomous Power Sharing: Introduction, Steady-state Operating Characteristics, Concept of Power Sharing, Power Sharing in MTDC Grid, AC–MTDC Grid Load flow Solution, Post-contingency Operation, Linear Model, Case Study. ■

Module-5

Frequency Support: Introduction, Fundamentals of Frequency Control, Inertial and Primary Frequency Support from Wind Farms, Wind Farms in Secondary Frequency Control (AGC), Modified Droop Control for Frequency Support, AC–MTDC Load Flow Solution, Post-Contingency Operation, Case Study.
Protection of MTDC Grids: Introduction, Converter Station Protection, DC Cable Fault Response, Fault-blocking Converters, DC Circuit Breakers, Protection Strategies. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Multi-Terminal Direct-Current Grids Modelling, Analysis, and Control	Nilanjan Ray Chaudhuri et al	Wiley	2014

(Group -6): 20EPE253 Embedded Systems

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Introduction to Embedded Systems: Embedded Systems, Processor Embedded into a System, Embedded Hardware Units and Devices in a System, Embedded Software in a System, Examples of Embedded Systems, Embedded Systems – on –chip (Soc) and Use of VLSI Circuit Design Technology, Complex Systems Design and Processors, Design of Process in Embedded System, Formulation of System Design, Design Process and Design Examples, Classification of Embedded Systems, Skill required for an Embedded System Designer. ■

Module-2

Processor Architecture and Memory Organisation: 8051 Architecture, Real world Interfacing, Introduction to Advanced Architecture, Processor and Memory Organization, Instruction Level Parallelism, Performance Metrics, Memory – Types, Memory – Maps and Addresses, Processor Selection, Memory Selection. ■

Module-3

Devices and Communication Buses, Interrupt Services: IO Types and Examples, Serial Communication Devices, Parallel Device Ports, Sophisticated Interfacing Features in Device Ports, Wireless Devices, Timer and Counting Devices, Watchdog Timer, Real Time Clock, Networked Embedded Systems, Serial Bus Device Protocols – Parallel Communication Network Using ISA,PCI, PCI –X and Advanced Protocols.

Device Drivers and Interrupts Service Mechanisms: Programmed – I/O Busy – wait Approach without Interrupt Service Mechanism, ISR Concept, Interrupt Sources, Interrupt Servicing Mechanism, Direct Memory Access. ■

Module-4

Program Modelling concepts: Program Models, DFG Models, State Machine Programming Models for Event – controlled Program Flow, Modelling of Multiprocessor Systems, UML Modelling.

Interprocess Communication and Synchronization of Processes, Threads and Tasks: Multiple Processes in an Application, Multiple Threads in an Application, Tasks, Task Status, Task and Data, Clear – cut Distention Between Functions, ISRS and Tasks by their Characteristics, Concept of Semaphores, Shared Data, Interprocess Communication, Signal Function, Semaphore Functions, Message Queue Functions, Mailbox Functions, Pipe Functions, Socket Functions, RPC Functions. ■

Module-5

Real - Time Operating Systems: OS Services, Process Management, Timer Functions, Event Functions, Memory management, Device, File and IO Subsystems Management , Interrupt Routines in RTOS Environment and Handling of Interrupt Source Calls, Real – time Operating Systems, Basic Design Using an RTOS, Rtos Task Scheduling Models, Interrupt Latency and Response of the task as performance Metrics, OS Security Issues. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Embedded Systems: Architecture, Programming and Design	Raj Kamal	Mc Graw Hill	2nd Edition,2014

(Group -6): 20EPE252 Digital Power Electronics

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Introduction: Historical review, Traditional parameters, Multiple-quadrant operations and choppers, Digital power electronics: pump circuits and conversion Technology, Shortage of analog power electronics and conversion technology, Power semiconductor devices applied in digital power electronics.
Energy Factor (EF) and Sub-sequential Parameters: Introduction, Pumping energy (PE), Stored energy (SE), Energy factor (EF), Variation energy factor (EFV),Time constant, τ, and damping time constant, τd, Examples of applications, Small signal analysis. ■

Module-2

Basic Mathematics of Digital Control Systems: Introduction, Digital Signals and Coding, Shannon's sampling theorem, Sample-and-hold devices, Analog-to-digital conversion, Digital-to-analog conversion, Energy quantization, Introduction to reconstruction of sampled signals, Data conversion: the zero-order hold, The first-order hold, The second-order hold, The Laplace transform (the s-domain), The z-transform (the z-domain),
Mathematical Modelling of Digital Power Electronics: Introduction, A zero-order hold (ZOH) for AC/DC controlled rectifiers, A first-order transfer function for DC/AC pulse-width-modulation Inverters, A second-order transfer function for DC/DC converters, A first-order transfer function for AC/AC (AC/DC/AC) converters. ■

Module-3

Digitally Controlled DC/AC Inverters: Introduction, Mathematical modelling for DC/AC PWM inverters, Single-phase half-wave VSI, Single-phase full-bridge PWM VSI, Three-phase full-bridge PWM VSI, Three-phase full-bridge PWM CSI, Multistage PWM inverter, Multilevel PWM inverter.
Digitally Controlled DC/DC Converters: Introduction, Mathematical Modelling for power DC/DC converters, Fundamental DC/DC converter, Developed DC/DC converters, Soft-switching converters, Multi-element resonant power converters. ■

Module-4

Digitally Controlled AC/AC Converters: Introduction, Traditional modelling for AC/AC (AC/DC/AC) converters, Single-phase AC/AC converter, Three-phase AC/AC voltage controllers, SISO cycloconverters, TISO cycloconverters, TITO cycloconverters, AC/DC/AC PWM converters, Matrix converters.
Open-loop Control for Digital Power Electronics: Introduction, Stability analysis, Unit-step function responses, Impulse responses. ■

Module-5

Closed-Loop Control for Digital Power Electronics: Introduction, PI control for AC/DC rectifiers, PI control for DC/AC inverters and AC/AC (AC/DC/AC) converters, PID control for DC/DC converters.
Energy Factor Application in AC and DC Motor Drives: Introduction, Energy storage in motors, A DC/AC voltage source, An AC/DC current source, AC motor drives, DC motor drives. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Digital Power Electronics and Applications	Fang Lin Luo, Hong Ye, Muhammad Rashid	Elsevier	2005

(Group -6): 20EPE254 Internet-Based Control Systems	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**
Module-1	
Introduction: Networked Control Systems (NCS), Internet-based Control Systems (ICS), Challenges of NCS/ICS. **Requirements Specification for Internet-based Control Systems:** Introduction, Requirements Specification, Functional Modelling of Internet-based Control Systems, Information Hierarchy, Possible Implementation of Information Architecture. **Internet-based Control System Architecture Design:** Introduction, Traditional Bilateral Tele-operation Systems, Remote Control over the Internet, Canonical Internet-based Control System Structures. **Web-based User Interface Design:** Features of Web-based User Interface, Multimedia User Interface Design, Case Study. ■	
Module-2	
Real-time Data Transfer over the Internet: Real-time Data Processing, Data Wrapped with XML, Real-time Data Transfer Mechanism, Case Study. **Dealing with Internet Transmission Delay and Data Loss from the Network View:** Requirements of Network Infrastructure for Internet-based Control, Features of Internet Communication, Comparison of TCP and UDP, Network Infrastructure for Internet-based Control, Typical Implementation for Internet-based Control. ■	
Module-3	
Dealing with Internet Transmission Delay and Data Loss from the Control Perspective: Overcoming the Internet Transmission Delay, Control Structure with the Operator Located Remotely, Internet-based Control with a Variable Sampling Time, Multi-rate Control, Time Delay Compensator Design, Simulation Studies, Experimental Studies. **Design of Multi-rate SISO Internet-based Control Systems:** Introduction, Discrete-time Multi-rate Control Scheme, Design Method, Stability Analysis, Simulation Studies, Real-time Implementation. ■	
Module-4	
Design of Multi-rate MIMO Internet-based Control Systems: Introduction, System Modeling, Controller Design, Stability Analysis, Design Procedure, Model-based Time Delay Compensation, Simulation Study. **Safety and Security Checking:** Introduction, Similarity of Safety and Security, Framework of Security Checking, Control Command Transmission Security, Safety Checking, Case Study. ■	
Module-5	
Remote Control Performance Monitoring and Maintenance over the Internet: Introduction, Performance Monitoring, Performance Monitoring of Control Systems, Remote Control Performance Maintenance, Case Study. **Remote Control System Design and Implementation over the Internet:** Introduction, Real-time Control System Life Cycle, Integrated Environments, A Typical Implementation of the General Integrated Environment, Case Study. ■	
Question paper pattern: The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60. • The question paper will have ten full questions carrying equal marks. • Each full question is for 20 marks. • There will be two full questions (with a maximum of four sub questions) from each module. • Each full question will have sub question covering all the topics under a module. • The students will have to answer five full questions, selecting one full question from each module.■	
Textbook	
1. Internet-based Control Systems: Design and Applications, Shuang - Hua Yang, Springer-Verlag, 2011.	

(Group -6): 20ECD251 Predictive Control of Drives

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Modelling of AC Drives and Power Converter: Space Phasor Representation, Model of Surface Mounted PMSM, Model of Interior Magnets PMSM, Per Unit Model and PMSM Parameters, Modelling of Induction Motor, Modelling of Power Converter.
Control of Semiconductor Switches via PWM Technologies: Topology of IGBT Inverter, Six-step Operating Mode, Carrier Based PWM, Space Vector PWM, Simulation Study of the Effect of PWM. ■

Module-2

PID Control System Design for Electrical Drives and Power Converters: Overview of PID Control Systems Using Pole-assignment Design Techniques, Overview of PID Control of PMSM, PI Controller Design for Torque Control of PMSM, Velocity Control of PMSM, PID Controller Design for Position Control of PMSM, Overview of PID Control of Induction Motor, PID Controller Design for Induction Motor, Overview of PID Control of Power Converter, PI Current and Voltage Controller Design for Power Converter.
PID Control System Implementation: P and PI Controller Implementation in Current Control Systems, Implementation of Current Controllers for PMSM, Implementation of Current Controllers for Induction Motors, Current Controller Implementation for Power Converter, Implementation of Outer-loop PI Control System, MATLAB Tutorial on Implementation of PI Controller. ■

Module-3

Tuning PID Control Systems with Experimental Validations: Sensitivity Functions in Feedback Control Systems, Tuning Current-loop q-axis Proportional Controller (PMSM), Tuning Current-loop PI Controller (PMSM), Performance Robustness in Outer-loop Controllers, Analysis of Time-delay Effects, Tuning Cascade PI Control Systems for Induction Motor, Tuning PI Control Systems for Power Converter, Tuning P Plus PI Controllers for Power Converter, Robustness of Power Converter Control System Using PI Current Controllers, Summary. ■

Module-4

FCS Predictive Control in d − q Reference Frame: States of IGBT Inverter and the Operational Constraints, FCS Predictive Control of PMSM, MATLAB Tutorial on Real-time Implementation of FCS-MPC, Analysis of FCS-MPC System, Overview of FCS-MPC with Integral Action, Derivation of I-FCS Predictive Control Algorithm, MATLAB Tutorial on Implementation of I-FCS Predictive Controller, I-FCS Predictive Control of Induction Motor, I-FCS Predictive Control of Power Converter, Evaluation of Robustness of I-FCS-MPC via Monte-Carlo Simulations, Velocity and Position Control of PMSM Using I-FCS-MPC,Velocity and Position Control of Induction Motor Using I-FCS-MPC, Summary. ■

Module-5

FCS Predictive Control in $a - Q$ Reference Frame: FCS Predictive Current Control of PMSM, Resonant FCS Predictive Current Control, Resonant FCS Current Control of Induction Motor, Resonant FCS Predictive Power Converter Control.
Discrete-time Model Predictive Control (DMPC) of Electrical Drives and Power Converter: Linear Discrete-time Model for PMSM, Discrete-time MPC Design with Constraints, Experimental Evaluation of DMPC of PMSM, Power Converter Control Using DMPC with Experimental Validation.
Continuous-time Model Predictive Control (CMPC) of Electrical Drives and Power Converter:
Continuous-time MPC Design, CMPC with Nonlinear Constraints, Simulation and Experimental Evaluation of CMPC of Induction Motor, Continuous-time Model Predictive Control of Power Converter, Gain Scheduled Predictive Controller, Experimental Results of Gain Scheduled Predictive Control of Induction Motor.■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook				
1	PID And Predictive Control of Electrical Drives and Power Converters Using Matlab®/Simulink®	Liuping Wang et al	Wiley	2015

(Group -6): 20ECD332 AC Drives with Inverter Output Filters

Exam Hours: 3 hours | **Exam Marks(Maximum):100**

Module-1

Electric Drives with LC Filters: Preliminary Remarks General Overview of AC Drives with Inverter Output Filters, Remarks on Simulation Examples.
Problems with AC Drives and Voltage Source Inverter Supply Effects: Effects Related to Common Mode Voltage, Determination of the Induction Motor CM Parameters, Prevention of Common Mode Current: Passive Methods, Active Systems for Reducing the CM Current, Common Mode Current Reduction by PWM Algorithm Modifications. ■

Module-2

Model of AC Induction Machine: Introduction, Inverse-Γ Model of Induction Machine, Per-Unit System, Machine Parameters, Simulation Examples.
Inverter Output Filters: Structures and Fundamentals of Operations, Output Filter Model, Design of Inverter Output Filters, dV/dt Filter, Motor Choke, Simulation Examples. ■

Module-3

Estimation of the State Variables in the Drive with LC Filter: Introduction, The State Observer with LC Filter Simulator, Speed Observer with Simplified Model of Disturbances, Speed Observer with Extended Model of Disturbances, Speed Observer with Complete Model of Disturbances, Speed Observer Operating for Rotating Coordinates, Speed Observer Based on Voltage Model of Induction Motor, Speed Observer with Dual Model of Stator Circuit, Adaptive Speed Observer, Luenberger Flux Observer, Simulation Examples. ■

Module-4

Control of Induction Motor Drives with LC Filters: Introduction, A Sinusoidal Filter as the Control Object, Field Oriented Control, Nonlinear Field Oriented Control, Multiscalar Control, Electric Drive with Load-Angle Control, Direct Torque Control with Space Vector Pulse Width Modulation, Simulation Examples.
Current Control of the Induction Motor: Introduction, Current Controller, Investigations, Simulation Examples of Induction Motor with Motor Choke and Predictive Control, Summary and Conclusions. ■

Module-5

Diagnostics of the Motor and Mechanical Side Faults: Introduction, Drive Diagnosis Using Motor Torque Analysis, Diagnosis of Rotor Faults in Closed-Loop Control, Simulation Examples of Induction Motor with Inverter Output Filter and Load Torque Estimation, Conclusions.
Multiphase Drive with Induction Motor and an LC Filter: Introduction, Model of a Five-Phase Machine, Model of a Five-Phase LC Filter, Five-Phase Voltage Source Inverter, Control of Five-Phase Induction Motor with an LC Filter, Speed and Flux Observer, Induction Motor and an LC Filter for Five-Phase Drive, Investigations of Five-Phase Sensorless Drive with an LC Filter, FOC Structure in the Case of Combination of Fundamental and Third Harmonic Currents, Simulation Examples of Five-Phase Induction Motor with a PWM Inverter. ■

Question Paper pattern:

- The question Paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Variable Speed AC drives with inverter Output Filters	Jaroslaw Guzinski et al	Wiley	2015

(Group -6): 20ECD322 FPGA and Programmable Logic	
Exam Hours: 3 hours	**Exam Marks(Maximum):100**
Module-1	
Recapitulation of combinational logic circuits. Timing hazards in combinational circuits. Introduction to the history and development of programmable logic. Birth of hardware description languages. Types of programmable logic devices, simple PLDs and CPLDs. ■	
Module-2	
Architecture of FPGA - generic features. Definition and construction of FPGA. Architecting an FPGA. Performance, density and capacity of an FPGA. Programmability issues. A study of the XC4000 configurable logic block. Introduction to major FPGA families, Xilinx, Altera and Cypress. ■	
Module-3	
Programming of FPGAs. Introduction to VHDL hardware description language. Programming elements, constructs and syntax. Entities and architecture, Creating combinational and synchronous logic. Details of function and procedures. Topics on identifiers, data objects, data types and attributes. Synthesis and fitting of designs. ■	
Module-4	
Simulation and verification of the programs. Considerations of area, speed and device resource utilization in FPGA technology. Creating test benches. Systematic study of implementing state machines using VHDL. ■	
Module-5	
FPGA versus CPLD and case studies. Pipe lining and resource sharing concepts. Applications of FPGA in electric drives and communication devices. Future advances in FPGA technology. ■	
Question paper pattern: The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60. • The question paper will have ten full questions carrying equal marks. • Each full question is for 20 marks. • There will be two full questions (with a maximum of four sub questions) from each module. • Each full question will have sub question covering all the topics under a module. • The students will have to answer five full questions, selecting one full question from each module. ■	
Text/Reference Books	
1. VHDL for Programmable logic, Kevin Skahill, Pearson Education, 2004.	
2. Digital Design, Principles and Practices, John F. Wakerly, Pearson Prentice Hall.	

(Group -6): 20ESE23 Power System Planning

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Power System Planning: Introduction, Power System Composition, The Planning Process, Power System Planning.
Factors Affecting the Future of Power Supply Industry: Introduction, Electricity Supply Industry Reform, Deregulation of Markets, Public Private Partnership Models, Environmental Considerations, Other Considerations Affecting the Power Industry Reform, Case Study.
Planning Criteria: Introduction, Planning Expansion, Power System Stability Concerns, Modeling and Performance Indicators, Power Quality (PQ) Considerations, Uncertainty Constraints and Risk Analysis Planning, Case Study: Generation Expansion Planning. ■

Module-2

Load Research: Introduction, Load Research Methodology, Sampling Design, Use of Load Research Results, Driving Factors, Load Modelling, Case Study.
Electricity Load Forecasting: Introduction, Classification Electrical Load Forecasting, Forecasting Perspectives, Forecasting Driving Factors, Forecasting Time Frames, Case Study.
Energy Efficiency: Introduction, Energy Efficiency Impact on Electricity Consumption, Appliance Efficiency, Building Efficiency, Improving Energy Efficiency, Incentives Mechanisms to Effect EE, Case Study.■

Module-3

Demand Side Management: Introduction, Concepts and Characteristics of Demand Side Management (DSM), Alternatives of DSM, Benefits of DSM, Implementation of DSM, Evaluation of DSM Alternatives, Case Study.
Renewable Energy Technologies: Introduction, RE and Electric Power, Green Energy and Sustainable Energy Generation, Site Specificity, RE Pricing, Production Economics, Environmental Impacts, Promoting of RE.
System Expansion Studies: Introduction, Generation Expansion, Transmission and Distribution Expansion, Cost Considerations and Expansion Obligations, Regulatory Incentives, Case Study. ■

Module-4

Integrated Resource Planning: Introduction, Concept and Rationale, Supply and Demand Side Interaction, Uncertainty and Cost Implications, Benefits of IRP, Case Study.
Interconnected Systems: Introduction, AC and HVDC Interconnection, Benefits of Interconnection, Interconnection: Technical Factors, Economic and Financial Impacts, Environmental Concerns, Social Impacts, Legal Aspects, Political Aspect.
Financing of Power Projects: Introduction, Economic Feasibility of Projects, Factors Influencing Investment in Power Systems, Financial vs. Economic Analyses, Financial Analysis Tools, Major Factors Influencing Financing, Financing Requirements, Public Private Partnership (PPP). ■

Module-5

Tariff Studies: Introduction, Tariff Calculation Models, Social Tariff Impacts, Cost-Reflective Tariff, Regulations and Tariffs, Case Study: Electricity Tariffs in Jordan (ERC, 2005), Net Paid Up Capital: JEPCO Prior to 2011.
Planning Tools: Introduction, Data Collection, Group Thinking, Decision Support Analysis, Decision Aiding Tools, Strategic Planning. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Power System Planning Technologies and Applications: Concepts, Solutions, and Management	Fawwaz Elkarmi	Engineering Science Reference (an imprint of IGI	2012

(Group -6): 20EMS332 Low Power VLSI (Very Large Scale Integration Design) Design

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Low Power VLSI Chips: Introduction, Needs for Low Power VLSI Chips, Charging and Discharging Capacitance, Short-circuit Current in CMOS Circuit, CMOS Leakage Current, Static Current, Basic Principles of Low Power Design, Low Power Figure of Merits.

Simulation Power Analysis: SPICE Circuit Simulation, Discrete Transistor Modelling and Analysis, Gate-level Logic Simulation, Architecture-level Analysis, Data Correlation Analysis in DSP Systems, Monte Carlo Simulation. ■

Module-2

Probabilistic Power Analysis: Random Logic Signals, Probability and Frequency, Probabilistic Power Analysis Techniques, Signal Entropy. ■

Module-3

Circuit: Transistor and Gate Sizing, Equivalent Pin Ordering, Network Restructuring and Reorganization, Special Latches and Flip-flops, Low Power Digital Cell Library, Adjustable Device Threshold Voltage.■

Module-4

Logic: Gate Reorganization, Signal Gating, Logic Encoding, State Machine Encoding, Precomputation Logic.

Special Techniques: Power Reduction in Clock Networks, CMOS Floating Node, Low Power Bus, Delay Balancing, Low Power Techniques for SRAM. ■

Module-5

Architecture and System: Power and Performance Management, Switching Activity Reduction, Parallel Architecture with Voltage Reduction, Flow Graph Transformation.

Advanced Techniques: Adiabatic Computation, Pass Transistor Logic Synthesis, Asynchronous Circuits. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	Practical Low Power Digital VLSI Design	Gary Yeap	Springer	1998

(Group -6): 20EMS323 Real Time Approach to Process Control

Exam Hours: 3 hours | **Exam Marks(Maximum):100**

Module-1

Control, simulation and Process control hardware fundamentals: Control, Simulation, Control system components, Primary elements, Final control elements. ■

Module-2

Fundamentals of single input–single output systems: Open-loop control, Disturbances, Feedback control overview, Feedback control: a closer look, Process attributes: capacitance and dead time, Process dynamic response, Process modelling and simulation.■

Module-3

Basic control modes: On–off control, Proportional (P-only) control, Integral (I-only) control, Proportional plus integral (PI) control, Derivative action, Proportional plus derivative (PD) controller, Proportional integral derivative (PID) control, Choosing the correct controller, Controller hardware.

Tuning feedback controllers: Quality of control and optimisation, Tuning methods. ■

Module-4

Advanced topics in classical automatic control: Cascade control, Feedforward control, Ratio control, Override control (auto selectors).

Common control loops: Flow loops, Liquid pressure loops, Liquid level control, Gas pressure loops, Temperature control loops, Pump control, Compressor control, Boiler control. ■

Module-5

Distillation column control: Basic terms, Steady-state and dynamic degrees of freedom, Control system objectives and design considerations, Methodology for selection of a controller structure, Level, pressure, temperature and composition control, Optimizing control, Distillation control scheme design using steady-state models, Distillation control scheme design using dynamic models.

Using steady-state methods in a multi-loop control scheme: Variable pairing, The relative gain array, Niederlinski index, Decoupling control loops, Tuning the controllers for multi-loop systems, Practical examples.

Plant-wide control: Short-term versus long-term control focus, Cascaded units, Recycle streams, General considerations for plant-wide control. ■

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook

1	A Real-Time Approach to Process Control	William Y. Svrcek	Wiley	2nd Edition, 2006