VISVESVARAYA TECHNOLOGICAL UNIVERSITY
BELAGAVI

Scheme of Teaching and Examinations and Syllabus

M.Tech POWER ELECTRONICS (EPE)

(Effective from Academic year 2020 - 21)

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI
Scheme of Teaching and Examinations – 2020 - 21
M.Tech POWER ELECTRONICS (EPE)
Choice Based Credit System (CBCS) and Outcome Based Education(OBE)

I SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching Hours per Week			Examination				Credits
				Theory	Practical	Skill Development Activities	Duration in hours	CIE Marks	SEE Marks	Total Marks	
				L	P	SDA					
1	PCC	20EEE11	Mathematical Methods In Control	03	--	02	03	40	60	100	4
2	PCC	20EPE12	Power Semiconductor Devices And Components	03	--	02	03	40	60	100	4
3	PCC	20EPE13	Power Electronic Converters	03	--	02	03	40	60	100	4
4	PCC	20EPE14	Modelling and Design of Controllers	03	--	02	03	40	60	100	4
5	PCC	20EPE15	Modelling and Analysis of Electrical Machines	03	--	02	03	40	60	100	4
6	PCC	20EPEL16	Power Electronics Laboratory-1	--	04	--	03	40	60	100	2
7	PCC	20RMI17	Research Methodology and IPR	01	--	02	03	40	60	100	2
			TOTAL	**17**	**04**	**12**	**21**	**280**	**420**	**700**	**24**

Note: PCC: Professional core.

Skill development activities:
Students and course instructor/s to involve either individually or in groups to interact together to enhance the learning and application skills.
The students should interact with industry (small, medium and large), understand their problems or foresee what can be undertaken for study in the form of research/ testing / projects, and for creative and innovative methods to solve the identified problem.
The students shall
(1) Gain confidence in modelling of systems and algorithms.
(2) Work on different software/s (tools) to Simulate, analyse and authenticate the output to interpret and conclude. Operate the simulated system under changed parameter conditions to study the system with respect to thermal study, transient and steady state operations, etc.
(3) Handle advanced instruments to enhance technical talent.
(4) Involve in case studies and field visits/ field work.
(5) Accustom with the use of standards/codes etc., to narrow the gap between academia and industry.
All activities should enhance student’s abilities to employment and/or self-employment opportunities, management skills, Statistical analysis, fiscal expertise, etc.

Internship: All the students have to undergo mandatory internship of 6 weeks during the vacation of I and II semesters and /or II and III semesters. A University examination shall be conducted during III semester and the prescribed internship credit shall be counted for the same semester. Internship shall be considered as a head of passing and shall be considered for the award of degree. Those, who do not take-up/complete the internship shall be declared as fail in internship course and have to complete the same during the subsequent University examination after satisfying the internship requirements.

Note: (i) Four credit courses are designed for 50 hours Teaching – Learning process.
(ii) Three credit courses are designed for 40 hours Teaching – Learning process.
(iii) Two credit courses are designed for 25 hours Teaching – Learning process.

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II SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching Hours /Week			Examination				Credits
				Theory	Practical/ seminar	Skill Development Activities	Duration in hours	CIE Marks	SEE Marks	Total Marks	
				L	P	SDA					
1	PCC	20EPE21	Electric Drives	03	--	02	03	40	60	100	4
2	PCC	20EPE22	Switched - Mode Power Supplies	03	--	02	03	40	60	100	4
3	PCC	20EPE23	Power System Harmonics	03	--	02	03	40	60	100	4
4	PEC	20EPE24X	Professional elective 1	04	--	--	03	40	60	100	4
5	PEC	20EPE25X	Professional elective 2	04	--	--	03	40	60	100	4
6	PCC	20EPEL26	Power Electronics Laboratory-2	--	04	--	03	40	60	100	2
7	PCC	20EPE27	Technical Seminar	--	02	--	--	100	--	100	2
TOTAL				**17**	**06**	**06**	**18**	**340**	**360**	**700**	**24**

Note: PCC: Professional core, PEC: Professional Elective.

Professional Elective 1		Professional Elective 2	
Course Code under 20EPE24X	**Course title**	**Course Code under 20EPE25X**	**Course title**
20EPE241	Converters for Solar and Wind Power Systems	20EPE251	Facts Controllers
20EPE242	Uninterruptible Power Supply	20EPE252	Digital Power Electronics
20EPE243	Hybrid Electric Vehicles	20EPE253	Embedded Systems
20EPE244	Neural and Fuzzy Logic Control of Drives	20EPE254	Internet-based Control Systems

Note:

1. Technical Seminar: CIE marks shall be awarded by a committee comprising of HoD as Chairman, Guide/co-guide, if any, and a senior faculty of the department. Participation in the seminar by all postgraduate students of the programme shall be mandatory.

The CIE marks awarded for Technical Seminar, shall be based on the evaluation of Seminar Report, Presentation skill and performance in Question and Answer session in the ratio 50:25:25.

2. Internship: All the students shall have to undergo mandatory internship of 6 weeks during the vacation of I and II semesters and /or II and III semesters. A University examination shall be conducted during III semester and the prescribed internship credit shall be counted in the same semester. Internship shall be considered as a head of passing and shall be considered for the award of degree. Those, who do not take-up/complete the internship shall be declared as fail in internship course and have to complete the same during the subsequent University examination after satisfying the internship requirements.

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III SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching Hours /Week			Examination				Credits
				Theory	Practical/ Mini –Project/ Internship	Skill Development activities	Duration in hours	CIE Marks	SEE Marks	Total Marks	
				L	P	SDA					
1	PCC	20EPE31	HVDC Power Transmission	03	--	02	03	40	60	100	4
2	PEC	20EPE32X	Professional elective 3	03	--	--	03	40	60	100	3
3	PEC	20EPE33X	Professional elective 4	03	--	--	03	40	60	100	3
4	Project	20EPE34	Project Work phase -1	--	02	--	--	100	--	100	2
5	PCC	20EPE35	Mini-Project	--	02	--	--	100	--	100	2
6	Internship	20EPEI36	Internship	(Completed during the intervening vacation of I and II semesters and /or II and III semesters.)			03	40	60	100	6
TOTAL				**09**	**04**	**02**	**12**	**360**	**240**	**600**	**20**

Note: PCC: Professional core, PEC: Professional Elective.

Professional elective 3		Professional elective 4	
Course Code under 20EPE32X	**Course title**	**Course Code under 20EPE33X**	**Course title**
20EPE321	MPPT in Solar Systems	20EPE331	Advanced Control Systems
20EPE322	EMC in Power Electronics	20EPE332	Power Quality Problems and Mitigation
20EPE323	Multilevel Converters for Industrial Applications	20EPE333	Multi-Terminal DC Grids
20EPE324	Data Analytics For The Smart Grid	20EPE334	Cybersecurity In The Electricity Sector

Note:

1. Project Work Phase-1: Students in consultation with the guide/co-guide if any, shall pursue literature survey and complete the preliminary requirements of selected Project work. Each student shall prepare relevant introductory project document, and present a seminar.

CIE marks shall be awarded by a committee comprising of HoD as Chairman, Guide/co-guide if any, and a senior faculty of the department. The CIE marks awarded for project work phase -1, shall be based on the evaluation of Project Report, Project Presentation skill and performance in Question and Answer session in the ratio 50:25:25.

SEE (University examination) shall be as per the University norms.

2. Internship: Those, who have not pursued /completed the internship shall be declared as fail in internship course and have to complete the same during subsequent University examinations after satisfying the internship requirements. Internship SEE (University examination) shall be as per the University norms.

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IV SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching Hours /Week		Examination				Credits
				Theory	Practical/ Field work	Duration in hours	CIE Marks	SEE Marks Viva voce	Total Marks	
				L	P					
1	Project	20EPE41	Project work phase -2	--	04	03	40	60	100	20
			TOTAL	--	**04**	**03**	**40**	**60**	**100**	**20**

Note:

1. Project Work Phase-2:

CIE marks shall be awarded by a committee comprising of HoD as Chairman, Guide/co-guide, if any, and a Senior faculty of the department. The CIE marks awarded for project work phase -2, shall be based on the evaluation of Project Report subjected to plagiarism check, Project Presentation skill and performance in Question and Answer session in the ratio 50:25:25.

SEE shall be at the end of IV semester. Project work evaluation and Viva-Voce examination (SEE), after satisfying the plagiarism check, shall be as per the University norms.

MATHEMATICAL METHODS IN CONTROL			
Course Code	20EEE11	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	60
Credits	04	Exam Hours	03

Module-1

Introduction to vector spaces and sub-spaces, definitions, illustrative example. Linearly independent and dependent vectors- Basis-definition and problems. Linear transformations-definitions. Matrix form of linear transformations- Illustrative examples. ■

Module-2

Solution of Systems of Linear Equations: Direct methods-Relaxation method, Partition method, Croute's Triangularisation method. Eigen values and Eigen vectors. Bounds on Eigen Values. Jacobi method & Givens method for symmetric matrices. ■

Module-3

Orthogonal vectors and orthogonal bases. Gram-Schmidt orthogonalization process. SVD and Applications. ■

Module-4

Probability: Random variables, Probability distributions: Binomial, Poisson, Normal distributions, Joint probability distribution (discrete and continuous)-Illustrative examples. ■

Module-5

Moments, central moments, characteristic functions, probability generating and moment generating functions- illustrations. Poisson, Gaussian and Erlang distributions-examples. ■

Course outcomes:

At the end of the course the student will be able to:

1. Understand the fundamentals of vector space and bases in reference to transformations.
2. Solve system of linear equations using direct and iterative methods.
3. Use the idea of Eigen values and Eigen vectors for the application of SVD.
4. Describe the basic notions of discrete and continuous probability distributions.
5. Find out responses of linear systems using statistical and probability tools. ■

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. ■

Textbooks

1. Linear Algebra and its Applications, David C.Lay et al, Pearson, 5th Edition, 2015.
2. Numerical Methods for Scientific and Engineering Computation, M. K. Jain et al, New Age International, 9th Edition, 2014.

Reference Books

1. Signals, Systems, and Inference, Alan V. Oppenheim and George C. Verghese, Pearson, 2012.
2. Numerical methods for Engineers, Steven C Chapra and Raymond P Canale, McGraw-Hill 7th Edition, 2015.
3. Higher Engineering Mathematics, B.S. Grewal, Khanna Publishers, 44th Edition, 2017.

POWER SEMICONDUCTOR DEVICES AND COMPONENTS			
Course Code	20EPE12	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	60
Credits	04	Exam Hours	03

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. ■

Course outcomes:

At the end of the course the student will be able to:

- Discuss power electronic concepts, electronic switches and semiconductor physics.
- Explain representation of switches in P-spice and power computations.
- Explain the internal structure, the principle of operation, characteristics and base drive circuits of power semiconductor devices; power diodes, power BJT, power MOSFET.
- Explain the internal structure, the principle of operation, characteristics and base drive circuits of power semiconductor devices; thyristors, power IGBT, power FET.

- Design Snubber circuits for the protection of power semiconductor devices.
- Design gate and base drive circuits for power semiconductor devices
- Design a heat sink to control the temperature rise of semiconductor devices
- Design magnetic components inductors and transformers used in the power electronic circuits. ■

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. 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, P. Antognetti, McGraw-Hill, 2nd Edition, 2010.
4. Power Semiconductor Devices, B. Jayant Baliga, Springer, 2008.
5. Power Electronics Principles and Applications, Joseph Vithayathil, McGraw-Hill, 2011.

POWER ELECTRONIC CONVERTERS			
Course Code	20EPE13	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	60
Credits	04	Exam Hours	03

Module-1

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-Overmodulation ($m_a > 1$), 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. ■

Course outcomes:

At the end of the course the student will be able to:

- Use the knowledge of PWM techniques in controlling different power electronic converters.
- Apply the knowledge of power electronics in design and analysis of DC –DC PWM converters.
- Design and analyze DC –AC and AC – DC converters and control their operation using PWM techniques.
- Design and analyze different resonant converters and their control circuits.
- Analyze AC – AC converters and multilevel converters. ■

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. 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.

MODELLING AND DESIGN OF CONTROLLERS			
Course Code	20EPE14	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	60
Credits	04	Exam Hours	03

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. ■

Course outcomes:

At the end of the course the student will be able to:

- Describe the role of computer simulations in the analysis and design of power electronics systems.
- Understand the functional modeling of static systems.
- Use sampling technique to determine a digital equivalent to a continuous time system.
- Understand the control basics of digital systems.
- Design digital controllers in discrete time and frequency domain.
- Design optimal and robust controllers by different methods.
- Explain essentials of discrete computation.■

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. 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.

MODELLING AND ANALYSIS OF ELECTRICAL MACHINES			
Course Code	20EPE15	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	60
Credits	04	Exam Hours	03

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. ■

Course outcomes:

At the end of the course the student will be able to:

- Explain the basic concepts of modeling.
- Develop mathematical models for DC motors for transient state analysis.
- Use reference frame theory to transform three phase to two phase.
- Develop dynamic model for three phase induction motor in stator ad rotor reference frames.
- Develop mathematical model of single phase transformers.
- Model synchronous machine using Park's transformation for the analysis of steady state operation.
- Model synchronous machine to perform dynamic analysis under different conditions.■

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/ Textbooks
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,
3. Analysis of Electrical Machinery and Drive Systems, P.C.Krause, et al, Wiley, 2nd Edition, 2010.
4. Power System Analysis, Arthur R Bergen and Vijay Vittal, Pearson, 2^{nd} Edition, 2009.
5. Power System Stability and Control, Prabha Kundur, Mc Graw Hill, 1^{st} Edition, 1994.
6. Dynamic Simulation of Electric Machinery using Matlab / Simulink, Chee-Mun Ong, Prentice Hall, 1998.

POWER ELECTRONICS LABORATORY-1			
Course Code	20EPEL16	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	0:4:0	SEE Marks	60
Credits	02	Exam Hours	03

Sl. NO	**Experiments**
1	Analysis of static and dynamic characteristic of MOSFET and IGBT.
2	Performance of single phase fully controlled and semi-controlled converter for RL load for continuous current mode.
3	Performance of single phase fully controlled and semi-controlled converter for RL load for discontinuous current mode.
4	Study of effect of source inductance on the performance of single phase fully controlled converter.
5	Performance analysis of three phase fully controlled and semi-controlled converter for RL load for continuous current mode.
6	Performance analysis of three phase fully controlled and semi-controlled converter for RL load for discontinuous current mode.
7	Performance analysis of single phase bridge inverter for RL load and voltage control by single pulse width modulation.
8	Performance analysis of two quadrant chopper.
9	Diode clamped multilevel inverter.
10	ZVS operation of a Synchronous buck converter.

Course outcomes:

At the end of the course the student will be able to:

- Analyze the static and dynamic characteristics of various semiconductor devices.
- Apply the knowledge of converters in assessing the performance of single phase and three phase fully controlled and semi controlled converters for RL load for continuous current modes.
- Apply the knowledge of converters in assessing the performance of single phase and three phase fully controlled and semi controlled converters for RL load for discontinuous current modes.
- Assess the performance of single phase bridge inverter for RL load and control the voltage by pulse width modulation.
- Apply the knowledge of power electronics in performance analysis of chopper and synchronous buck converter.■

RESEARCH METHODOLOGY AND IPR			
Course Code	20RMI17	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	1:0:2	SEE Marks	60
Credits	02	Exam Hours	03

Module-1

Research Methodology: Introduction, Meaning of Research, Objectives of Research, Motivation in Research, Types of Research, Research Approaches, Significance of Research, Research Methods versus Methodology, Research and Scientific Method, Importance of Knowing How Research is Done, Research Process, Criteria of Good Research, and Problems Encountered by Researchers in India.

Defining the Research Problem: Research Problem, Selecting the Problem, Necessity of Defining the Problem, Technique Involved in Defining a Problem, An Illustration. ■

Module-2

Reviewing the literature: Place of the literature review in research, Bringing clarity and focus to your research problem, Improving research methodology, Broadening knowledge base in research area, Enabling contextual findings, How to review the literature, searching the existing literature, reviewing the selected literature, Developing a theoretical framework, Developing a conceptual framework, Writing about the literature reviewed.

Research Design: Meaning of Research Design, Need for Research Design, Features of a Good Design, Important Concepts Relating to Research Design, Different Research Designs, Basic Principles of Experimental Designs, Important Experimental Designs. ■

Module-3

Design of Sampling: Introduction, Sample Design, Sampling and Non-sampling Errors, Sample Survey versus Census Survey, Types of Sampling Designs.

Measurement and Scaling: Qualitative and Quantitative Data, Classifications of Measurement Scales, Goodness of Measurement Scales, Sources of Error in Measurement Tools, Scaling, Scale Classification Bases, Scaling Technics, Multidimensional Scaling, Deciding the Scale.

Data Collection: Experimental and Surveys, Collection of Primary Data, Collection of Secondary Data, Selection of Appropriate Method for Data Collection, Case Study Method. ■

Module-4

Testing of Hypotheses: Hypothesis, Basic Concepts Concerning Testing of Hypotheses, Testing of Hypothesis, Test Statistics and Critical Region, Critical Value and Decision Rule, Procedure for Hypothesis Testing, Hypothesis Testing for Mean, Proportion, Variance, for Difference of Two Mean, for Difference of Two Proportions, for Difference of Two Variances, P-Value approach, Power of Test, Limitations of the Tests of Hypothesis.

Chi-square Test: Test of Difference of more than Two Proportions, Test of Independence of Attributes, Test of Goodness of Fit, Cautions in Using Chi Square Tests. ■

Module-5

Interpretation and Report Writing: Meaning of Interpretation, Technique of Interpretation, Precaution in Interpretation, Significance of Report Writing, Different Steps in Writing Report, Layout of the Research Report, Types of Reports, Oral Presentation, Mechanics of Writing a Research Report, Precautions for Writing Research Reports.

Intellectual Property: The Concept, Intellectual Property System in India, Development of TRIPS Complied Regime in India, Patents Act, 1970, Trade Mark Act, 1999,The Designs Act, 2000, The Geographical Indications of Goods (Registration and Protection) Act1999, Copyright Act,1957,The Protection of Plant Varieties and Farmers' Rights Act, 2001,The Semi-Conductor Integrated Circuits Layout Design Act, 2000, Trade Secrets, Utility Models, IPR and Biodiversity, The Convention on Biological Diversity (CBD) 1992, Competing Rationales for Protection of IPRs, Leading International Instruments Concerning IPR, World Intellectual Property Organisation (WIPO),WIPO and WTO, Paris Convention for the Protection of Industrial Property, National Treatment, Right of Priority, Common Rules, Patents, Marks, Industrial Designs, Trade Names, Indications of Source, Unfair Competition,

Patent Cooperation Treaty (PCT), Advantages of PCT Filing, Berne Convention for the Protection of Literary and Artistic Works, Basic Principles, Duration of Protection, Trade Related Aspects of Intellectual Property Rights(TRIPS) Agreement, Covered under TRIPS Agreement, Features of the Agreement, Protection of Intellectual Property under TRIPS, Copyright and Related Rights, Trademarks, Geographical indications, Industrial Designs, Patents, Patentable Subject Matter, Rights Conferred, Exceptions, Term of protection, Conditions on Patent Applicants, Process Patents, Other Use without Authorization of the Right Holder, Layout-Designs of Integrated Circuits, Protection of Undisclosed Information, Enforcement of Intellectual Property Rights, UNSECO. ■

Course outcomes:

At the end of the course the student will be able to:

- Discuss research methodology and the technique of defining a research problem
- Explain the functions of the literature review in research, carrying out a literature search, developing theoretical and conceptual frameworks and writing a review.
- Explain various research designs, sampling designs, measurement and scaling techniques and also different methods of data collections.
- Explain several parametric tests of hypotheses, Chi-square test, art of interpretation and writing research reports
- Discuss various forms of the intellectual property, its relevance and business impact in the changing global business environment and leading International Instruments concerning IPR. ■

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. Research Methodology: Methods and Techniques, C.R. Kothari, Gaurav Garg, New Age International, 4th Edition, 2018.
2. Research Methodology a step-by-step guide for beginners, Ranjit Kumar, SAGE Publications, 3rd Edition, 2011. (For the topic Reviewing the literature under module 2),
3. Study Material (For the topic Intellectual Property under module 5), Professional Programme Intellectual Property Rights, Law and Practice, The Institute of Company Secretaries of India, Statutory Body Under an Act of Parliament, September 2013.

Reference Books

1. Research Methods: the concise knowledge base, Trochim, Atomic Dog Publishing, 2005.
2. Conducting Research Literature Reviews: From the Internet to Paper, Fink A, Sage Publications, 2009.

*** END ***

ELECTRIC DRIVES			
Course Code	20EPE21	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	60
Credits	04	Exam Hours	03

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. ■

Course outcomes:
At the end of the course the student will be able to:
- Explain characteristics of DC motors, induction motors and synchronous motors.
- Explain braking of electric motors.
- Classify electric drives.
- Discuss dynamics conditions and stability considerations of Electric drive.
- Control the speed of electric motors.
- Suggest a drive for a specific application.
- Explain using microprocessor in the control of an electric drive. ■

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. Electric Drives Concepts and Applications, Vedam Subrahmanyam, Mc Graw Hill, 2nd Edition, 2016.

Reference Books

1. Fundamentals of Industrial Drives, B.N.Sarkar, PHI, 2012.
2. Fundamentals of Electrical Drives, Gopal K Dubey, Narosa Book Distributors, 2010.
3. Electric Drives, Nisit K. De, Prasanta K Sen, PHI, 1st Edition, 2014.

SWITCHED - MODE POWER SUPPLIES			
Course Code	20EPE22	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	60
Credits	04	Exam Hours	03

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. ■

Course outcomes:

At the end of the course the student will be able to:

- Explain a SMPS, its characteristics, new technologies, basic principles and control modes.
- Suggest a suitable DC/DC converter for an SMPS.
- Explain the method of selecting key peripheral components of SMPS.
- Design the power factor correction circuit of SMPS.
- Explain selection of magnetic core and designing of high-frequency transformer.
- Explain designing of different SMPS.
- Explain testing technology of SMPS.
- Design protection and monitoring circuit for SMPS.■

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

POWER SYSTEM HARMONICS			
Course Code	20EPE23	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	60
Credits	04	Exam Hours	03

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. ■

Course outcomes:

At the end of the course the student will be able to:

- Explain the fundamentals that facilitate the understanding of the issues of harmonics.
- Explain the causes for generation of harmonics.
- Explain the effects of harmonics distortion on power system equipment and loads and suppression of harmonics in power systems.
- Discuss standard limits of harmonic distortion and modeling of power system components for harmonic analysis study.
- Model transmission lines and cables for harmonic analysis.
- Discuss implementation of harmonic studies.■

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. 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

CONVERTERS FOR SOLAR AND WIND POWER SYSTEMS			
Course Code	20EPE241	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	4:0:0	SEE Marks	60
Credits	04	Exam Hours	03

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. ■

Course outcomes:

At the end of the course the student will be able to:

- Explain developments in the PV and WT penetrations in the worldwide power systems.
- Discuss the various high-efficiency topologies for PV inverters and generic control structures.
- Describe the grid requirements for PV installations, and different quadrature signal generator methods,
- Explain grid synchronization techniques for single phase power converters.
- Explain islanding detection methods and typical WT grid converter topologies, control structures, the grid requirements for WT grid connection and the grid codes.
- Explain grid synchronization of three phase power converters and new robust synchronization structures to cope with the unbalance and distorted grid conditions.
- Explain the grid converter control structures for WT and the control issue for the case of grid faults.
- Design grid interface filters used to damp the resonance for LCL filters and methods for controlling the grid current. ■

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

UNINTERRUPTIBLE POWER SUPPLY			
Course Code	20EPE242	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	4:0:0	SEE Marks	60
Credits	04	Exam Hours	03

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. ■

Course outcomes:
At the end of the course the student will be able to:

- Explain classification of UPS, batteries for UPS, parallel operation and performance evaluation and control of UPS systems.
- Describe sources of harmonics and their mitigation using active filters.
- Describe topologies of active filters, their applications, control methods, modeling analysis, and stability issues.
- Explain steady-state operation and control of unified power quality conditioners.
- Explain an on-line ups system based on novel AC/DC rectifier.
- Explain the concept of reduced parts active filters, their modeling and control. ■

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. 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-ill, 2003.

HYBRID ELECTRIC VEHICLES			
Course Code	20EPE243	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	4:0:0	SEE Marks	60
Credits	04	Exam Hours	03

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. ■

Course outcomes:
At the end of the course the student will be able to:

- Explain the basics of electric and hybrid electric vehicles, their architecture, technologies and fundamentals.
- Explain plug – in hybrid electric vehicle architecture, design and component sizing.
- Explain the use of different power electronics devices in hybrid electric vehicles.
- Suggest a suitable electric drive for a specific type of hybrid electric vehicle.
- Explain the use of different energy storage devices used for hybrid electric vehicles, their technologies and control.
- Simulate electric hybrid vehicles by different techniques for the performance analysis. ■

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

NEURAL AND FUZZY LOGIC CONTROL OF DRIVES			
Course Code	20EPE244	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	4:0:0	SEE Marks	60
Credits	04	Exam Hours	03

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.■

Course outcomes:

At the end of the course the student will be able to:

- Discuss control strategies for electric drives/power systems.
- Understand the complex features of control strategies, EDA, neural networks, fuzzy logic, electric machines and drives, power systems and VHDL. ■

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.

FACTS CONTROLLERS			
Course Code	20EPE251	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	4:0:0	SEE Marks	60
Credits	04	Exam Hours	03

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. ■

Course outcomes:
At the end of the course the student will be able to:

- Discuss the growth of complex electrical power networks, the lack of controllability of the active- and reactive-power flows in energized networks.
- Describe the conventional controlled systems and the basic operating principles of FACTS.
- Describe the various components of a general SVC, its control system, control characteristics and the design of the SVC voltage regulator.
- Explain the use of SVC in stability enhancement, damping subsynchronous oscillations, improvement of HVDC link performance.
- Explain the concepts of series compensation, TCSC controller and its operation, characteristics, modeling and applications.
- Explain the operation of voltage source converter based FACTS. ■

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. 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.

DIGITAL POWER ELECTRONICS			
Course Code	20EPE252	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	4:0:0	SEE Marks	60
Credits	04	Exam Hours	03

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. ■

Course outcomes:

At the end of the course the student will be able to:

- Explain traditional parameters computation, multiple quadrant operation and choppers.
- Explain the disadvantages of analog power electronics and conversion technology, energy factor and sub-sequential parameters.
- Explain basic mathematics of digital control systems and mathematical modeling of digitally controlled power electronic devices such as rectifiers, inverters and converters.
- Describe mathematical modeling of AC/DC rectifiers, DC/AC inverters, DC/DC converters and AC/AC (AC/DC/AC) converters are working in the discrete-time state.
- Discuss DC/AC pulse-width-modulation (PWM) inverters and AC /AC converters modeled as a first-order-hold (FOH) element in digital control systems.
- Discuss DC/DC converter modeled as a second order-hold (SOH) element in digital control systems.
- To explain open loop and closed loop control of power electronic devices and energy factor application of AC and DC motor drives.■

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

EMBEDDED SYSTEMS			
Course Code	20EPE253	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	4:0:0	SEE Marks	60
Credits	04	Exam Hours	03

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. ■

Course outcomes:
At the end of the course the student will be able to:

- Explain design process in embedded system and formulation of system design.
- Describe processor architecture and memory organization.
- Describe the devices; serial port, parallel port devices, timing devices, devices for synchronous iso-synchronous and asynchronous communication.
- Describe device drivers and interrupt mechanisms.
- Explain the programming concepts and source code engineering tools for embedded programming.
- Explain real time programming and program modeling concepts during single and multi-processor system software development process.
- Describe real time operating systems concepts. ■

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

INTERNET-BASED CONTROL SYSTEMS			
Course Code	20EPE254	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	4:0:0	SEE Marks	60
Credits	04	Exam Hours	03

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. ■

Course outcomes:
At the end of the course the student will be able to:
- Discuss requirements for Internet-based control systems and to building a functional model, traditional tele-operation systems and Web-based user interface design.
- Discuss Real-time Data Transfer over the Internet dealing with Internet Transmission Delay and Data Loss from the Network View and Control perspective.
- Discuss design of Multi-rate SISO and MIMO Internet-based Control Systems and Safety and Security Checking.
- Explain the basic concepts and general guidelines of control system performance monitoring, remotely designing, testing, and updating real-time control software through the Internet. ■

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.

POWER ELECTRONICS LABORATORY-2			
Course Code	20EPEL26	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	0:4:0	SEE Marks	60
Credits	02	Exam Hours	03

Sl. NO	**Experiments**
1	Study and performance analysis of single phase fully controlled converter fed separately excited DC Motor for continuous current mode.
2	Study and performance analysis of single phase fully controlled converter fed separately excited DC Motor for discontinuous current mode.
3	Study and performance analysis of three phase fully controlled converter fed separately excited DC Motor for continuous current mode.
4	Study and performance analysis of three phase fully controlled converter fed separately excited DC Motor for discontinuous current mode.
5	Performance analysis of a practical chopper fed DC Drives system for class-A and class-C commutation and analysis of wave forms in continuous mode.
6	Simulation study of buck, boost and buck- boost converter (basic topologies) and analysis of wave forms for continuous current mode (CCM).
7	Simulation study of buck, boost and buck-boost converter (basic topologies) and analysis of wave forms for discontinuous current mode (DCM).
8	Simulation study of forward converter and fly back converter and performance analysis of various wave forms.
9	Resonant converter simulation study and analysis.
10	Closed loop operation of a buck and boost converter.

Course outcomes:

At the end of the course the student will be able to:

- Conduct experiments on single phase / three phase fully controlled converter fed separately excited DC motor to assess the performance in continuous and discontinuous current modes.
- Conduct experiments to assess the performance of Chopper fed DC drives for class A and class C commutation in continuous current mode.
- Simulate different converters for analyzing the waveform in continuous and discontinuous current modes.
- Simulate forward converter, fly back converter and resonant converter to study their performance. ■

TECHNICAL SEMINAR			
Course Code	20EPE27	CIE Marks	100
Number of contact Hours/week	0:0:2	SEE Marks	--
Credits	02	Exam Hours	--

Course objectives:

The objective of the seminar is to inculcate self-learning, face audience confidently, enhance communication skill, involve in group discussion and present and exchange ideas.

Each student, under the guidance of a Faculty, is required to

- Choose, preferably through peer reviewed journals, a recent topic of his/her interest relevant to the Course of Specialization.
- Carryout literature survey, organize the Course topics in a systematic order.
- Prepare the report with own sentences.
- Type the matter to acquaint with the use of Micro-soft equation and drawing tools or any such facilities.
- Present the seminar topic orally and/or through power point slides.
- Answer the queries and involve in debate/discussion.
- Submit two copies of the typed report with a list of references.

The participants shall take part in discussion to foster friendly and stimulating environment in which the students are motivated to reach high standards and become self-confident.

The CIE marks for the seminar shall be awarded (based on the relevance of the topic, presentation skill, participation in the question and answer session and quality of report) by the committee constituted for the purpose by the Head of the Department. The committee shall consist of three faculties from the department with the senior most acting as the Chairperson. ■

Marks distribution for CIE of the course 20EPE27 seminar:

Seminar Report: 30 marks

Presentation skill:50 marks

Question and Answer:20 marks

*** END ***

HVDC POWER TRANSMISSION			
Course Code	20EPE31	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	60
Credits	04	Exam Hours	03

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, 10.4 Multi-Terminal DC Transmission.

Trends for HVDC Applications: Wind Farm Technology, Modern Voltage Source Converter (VSC) HVDC Systems, 800 kV HVDC System. ■

Course outcomes:

At the end of the course the student will be able to:

- Explain importance of DC power transmission.
- Describe the basic components of a converter, the methods for compensating the reactive power demanded by the converter
- Explain the methods for simulation of HVDC systems and its control.
- Describe filters for eliminating harmonics and the characteristics of the system impedance resulting from AC filter designs
- Explain the design techniques for the main components of an HVDC system.
- Explain the protection of HVDC system and other converter configurations used for the HVDC transmission.
- Explain the recent trends for HVDC applications.■

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. 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 Power Transmission Systems, K. R. Padiyar, New Age International, 2012.

<table>
<tr><th colspan="4">MPPT IN SOLAR SYSTEMS</th></tr>
<tr><td>Course Code</td><td>20EPE321</td><td>CIE Marks</td><td>40</td></tr>
<tr><td>Teaching Hours/Week (L:P:SDA)</td><td>3:0:0</td><td>SEE Marks</td><td>60</td></tr>
<tr><td>Credits</td><td>03</td><td>Exam Hours</td><td>03</td></tr>
<tr><td colspan="4">Module-1</td></tr>
<tr><td colspan="4">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. ■</td></tr>
<tr><td colspan="4">Module-2</td></tr>
<tr><td colspan="4">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. ■</td></tr>
<tr><td colspan="4">Module-3</td></tr>
<tr><td colspan="4">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. ■</td></tr>
<tr><td colspan="4">Module-4</td></tr>
<tr><td colspan="4">Distributed Maximum Power Point Tracking of Photovoltaic Arrays (continued): AC Analysis of a PV Array with DMPPT. ■</td></tr>
<tr><td colspan="4">Module-5</td></tr>
<tr><td colspan="4">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. ■</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4">Course outcomes:
At the end of the course the student will be able to:
Explain the PV cell, its characteristics and its models, equivalent circuits and circuit parameter calculations.
Explain different methods of tracking maximum power point.
Explain the sources of noise, effect of noise on MPPT and reduction of noise.
Explain Distributed Maximum Power Point Tracking of PV arrays.
Conduct DC analysis of PV array with DMPPT.
Conduct AC analysis of PV array with DMPPT.
Explain the use of high energy efficiency power converters for PV MPPT application. ■</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td colspan="4">Textbook</td></tr>
<tr><td colspan="4">1. Power electronics and Control Techniques for Maximum energy harvesting in Photovoltaic systems, Nicola</td></tr>
</table>

EMC IN POWER ELECTRONICS			
Course Code	20EPE322	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	60
Credits	03	Exam Hours	03

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. ■

Course outcomes:
At the end of the course the student will be able to:

- Describe Electromagnetic interference and its classification and measurement of conducted high frequency disturbance.
- Survey electromagnetic interference specific to power electronic equipment.
- Explain the characteristics of circuit elements used for noise suppression.
- Explain EMI suppression methods used in semiconductor and electromechanical devices.
- Explain design of EMI filter circuits and filtering methods.
- Explain susceptibility and noise withstand capability test.
- Explain EMS reduction techniques for power electronic equipment. ■

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

MULTILEVEL CONVERTERS FOR INDUSTRIAL APPLICATIONS			
Course Code	20EPE323	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	60
Credits	03	Exam Hours	03

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. ■

Course outcomes:
At the end of the course the student will be able to:
- Explain the working of medium-voltage power converters and their applications.
- Explain multilevel, symmetric and asymmetric topologies.
- Explain the structure and operation of the diode-clamped multilevel converter, and a multilevel space vector modulation.
- Characterize the balancing boundary of the passive front-end converter.
- Describe the operation and analysis of the flying capacitor multilevel converter.
- Discuss the characteristics topologies of the Cascade Asymmetric Multilevel Controller.
- Explain the working of a distribution static compensator (DSTATCOM) built with CAMC for reactive power and harmonic compensation.
- Evaluate the performance of back-to-back converter in an induction motor drive for several working conditions. ■

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

DATA ANALYTICS FOR THE SMART GRID			
Course Code	20EPE324	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	4:0:0	SEE Marks	60
Credits	04	Exam Hours	03

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. ■

Course outcomes:

At the end of the course the student will be able to:

- Discuss the key role of data analytics; its architecture and the challenges of creating and implementing them.
- Discuss useful analytical models, traditional business functions and issues affecting how analytics are used in the control room.
- Discuss the methods to increase residential customer lifetime value, vulnerabilities, threats, and analytic approaches to responding to cyber warfare against the utility,
- Discuss the elements of big data infrastructure, their difficulties and benefits in adapting to the needs of high-volume and varied data types,
- Explain the basic concepts of data visualization and the importance of utility becoming trusted steward of big data. ■

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.

ADVANCED CONTROL SYSTEMS			
Course Code	20EPE331	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	60
Credits	03	Exam Hours	03

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. ■

Course outcomes:

At the end of the course the student will be able to:

- Evaluate Z transform of a continuous time signal.
- Assess the stability of a system in Z domain.
- Explain the process of reconstructing the analog signal from a digital signal.
- Model the digital systems to analyze them in the digital domain.
- Use state variable representation to design control law and observers for a system in both continuous and discrete time domains.
- Solve optimal control problems.
- Construct Lyapunov functions to evaluate the stability of a system.
- Use describing function, phase plane methods and Lyapunov method to assess the stability of the nonlinear system. ■

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. Digital Control and State Variable Methods (Conventional and Intelligent Control Systems), M Gopal, Mc Graw

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.

POWER QUALITY PROBLEMS AND MITIGATION			
Course Code	20EPE332	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	60
Credits	03	Exam Hours	03

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. ■

Course outcomes:

At the end of the course the student will be able to:

- Explain causes, effects of PQ problems and classification of mitigation techniques for PQ problems.
- Explain PQ standards, terminology and monitoring requirements through numerical problems.
- Explain passive shunt and series compensation using lossless passive components.
- Explain the design, operation and modeling of active shunt compensation equipment.
- Explain the design, operation and modeling of active series compensation equipment.
- Explain the design operation and modeling of unified power quality compensators.
- Discuss mitigation of power quality problems due to nonlinear loads.■

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

MULTI-TERMINAL DC GRIDS			
Course Code	20EPE333	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	60
Credits	03	Exam Hours	03

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. ■

Course outcomes:
At the end of the course the student will be able to:
- Explain the fundamentals of MTDC grids, their network architectures, components and control modes
- Differentiate ideal and practical voltage sourced converters.
- Simulate AC- MTDC grids for the analysis.
- Explain the concept of power sharing in MTDC grid, load flow solution and post contingency operation.
- Explain frequency support from wind farms.
- Explain protection issues of MTDC grids, including the DC circuit breakers and fault blocking VSC systems and protection strategies.■

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

CYBERSECURITY IN THE ELECTRICITY SECTOR			
Course Code	20EPE334	CIE Marks	40
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	60
Credits	03	Exam Hours	03

Module-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. ■

Course outcomes:
At the end of the course the student will be able to:

- Discuss the current cybersecurity situation in the electricity sector and the relevant standards that can be employed for cybersecurity.
- Explain cybersecurity management approach and the methods for the electricity sector.
- Explain available solutions that support the cost-benefit analyses involved in cybersecurity management and cybersecurity assessment approach.
- Discuss cybersecurity controls, for reducing cyber risks. ■

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

PROJECT WORK PHASE – 1			
Course Code	20EPE34	CIE Marks	100
Number of contact Hours/Week	0:0:2	SEE Marks	--
Credits	02	Exam Hours	--

Course objectives:

- Support independent learning.
- Guide to select and utilize adequate information from varied resources maintaining ethics.
- Guide to organize the work in the appropriate manner and present information (acknowledging the sources) clearly.
- Develop interactive, communication, organisation, time management, and presentation skills.
- Impart flexibility and adaptability.
- Inspire independent and team working.
- Expand intellectual capacity, credibility, judgement, intuition.
- Adhere to punctuality, setting and meeting deadlines.
- Instil responsibilities to oneself and others.
- Train students to present the topic of project work in a seminar without any fear, face audience confidently, enhance communication skill, involve in group discussion to present and exchange ideas. ■

Project Phase-1 Students in consultation with the guide/s shall carry out literature survey/ visit industries to finalize the topic of the Project. Subsequently, the students shall collect the material required for the selected project, prepare synopsis and narrate the methodology to carry out the project work.

Seminar: Each student, under the guidance of a Faculty, is required to

- Present the seminar on the selected project orally and/or through power point slides.
- Answer the queries and involve in debate/discussion.
- Submit two copies of the typed report with a list of references.

The participants shall take part in discussion to foster friendly and stimulating environment in which the students are motivated to reach high standards and become self-confident. ■

Course outcomes:

At the end of the course the student will be able to:

- Demonstrate a sound technical knowledge of their selected project topic.
- Undertake problem identification, formulation and solution.
- Design engineering solutions to complex problems utilising a systems approach.
- Communicate with engineers and the community at large in written an oral forms.
- Demonstrate the knowledge, skills and attitudes of a professional engineer. ■

Continuous Internal Evaluation

CIE marks for the project report (50 marks), seminar (30 marks) and question and answer (20 marks) shall be awarded (based on the quality of report and presentation skill, participation in the question and answer session by the student) by the committee constituted for the purpose by the Head of the Department. The committee shall consist of three faculty from the department with the senior most acting as the Chairperson. ■

MINI PROJECT			
Course Code	20EPE35	CIE Marks	40
Number of contact Hours/Week	(0:0:2)	SEE Marks	60
Credits	02	Exam Hours/Batch	03

Course objectives:

- To support independent learning and innovative attitude.
- To guide to select and utilize adequate information from varied resources upholding ethics.
- To guide to organize the work in the appropriate manner and present information (acknowledging the sources) clearly.
- To develop interactive, communication, organisation, time management, and presentation skills.
- To impart flexibility and adaptability.
- To inspire independent and team working.
- To expand intellectual capacity, credibility, judgement, intuition.
- To adhere to punctuality, setting and meeting deadlines.
- To instil responsibilities to oneself and others.
- To train students to present the topic of project work in a seminar without any fear, face audience confidently, enhance communication skill, involve in group discussion to present and exchange ideas. ■

Mini-Project: Each student of the project batch shall involve in carrying out the project work jointly in constant consultation with internal guide, co-guide, and external guide and prepare the project report as per the norms avoiding plagiarism. ■

Course outcomes:

At the end of the course the student will be able to:

- Present the mini-project and be able to defend it.
- Make links across different areas of knowledge and to generate, develop and evaluate ideas and information so as to apply these skills to the project task.
- Habituated to critical thinking and use problem solving skills.
- Communicate effectively and to present ideas clearly and coherently in both the written and oral forms.
- Work in a team to achieve common goal.
- Learn on their own, reflect on their learning and take appropriate actions to improve it. ■

CIE procedure for Mini - Project:

The CIE marks awarded for Mini - Project, shall be based on the evaluation of Mini - Project Report, Project Presentation skill and Question and Answer session in the ratio 50:25:25.The marks awarded for Mini - Project report shall be the same for all the batch mates.

Semester End Examination

SEE marks for the mini-project shall be awarded based on the evaluation of Mini-Project Report, Presentation skill and Question and Answer session in the ratio 50:25:25 by the examiners appointed by the University. ■

INTERNSHIP / PROFESSIONAL PRACTICE			
Course Code	20EPEI36	CIE Marks	40
Number of contact Hours/Week	2	SEE Marks	60
Credits	06	Exam Hours	03

Course objectives:

Internship/Professional practice provide students the opportunity of hands-on experience that include personal training, time and stress management, interactive skills, presentations, budgeting, marketing, liability and risk management, paperwork, equipment ordering, maintenance, responding to emergencies etc. The objective are further,

To put theory into practice.

To expand thinking and broaden the knowledge and skills acquired through course work in the field.

To relate to, interact with, and learn from current professionals in the field.

To gain a greater understanding of the duties and responsibilities of a professional.

To understand and adhere to professional standards in the field.

To gain insight to professional communication including meetings, memos, reading, writing, public speaking, research, client interaction, input of ideas, and confidentiality.

To identify personal strengths and weaknesses.

To develop the initiative and motivation to be a self-starter and work independently. ■

Internship/Professional practice: Students under the guidance of internal guide/s and external guide shall take part in all the activities regularly to acquire as much knowledge as possible without causing any inconvenience at the place of internship.

Seminar: Each student, is required to

- Present the seminar on the internship orally and/or through power point slides.
- Answer the queries and involve in debate/discussion.
- Submit the report duly certified by the external guide.
- The participants shall take part in discussion to foster friendly and stimulating environment in which the students are motivated to reach high standards and become self-confident. ■

Course outcomes:

At the end of the course the student will be able to:

- Gain practical experience within industry in which the internship is done.
- Acquire knowledge of the industry in which the internship is done.
- Apply knowledge and skills learned to classroom work.
- Develop a greater understanding about career options while more clearly defining personal career goals.
- Experience the activities and functions of professionals.
- Develop and refine oral and written communication skills.
- Identify areas for future knowledge and skill development.
- Expand intellectual capacity, credibility, judgment, intuition.
- Acquire the knowledge of administration, marketing, finance and economics. ■

Continuous Internal Evaluation

CIE marks for the Internship/Professional practice report (20 marks), seminar (10 marks) and question and answer session (10 marks) shall be awarded (based on the quality of report and presentation skill, participation in the question and answer session by the student) by the committee constituted for the purpose by the Head of the Department. The committee shall consist of three faculty from the department with the senior most acting as the Chairperson. ■

Semester End Examination

SEE marks for the internship report (30 marks), seminar (20 marks) and question and answer session (10 marks) shall be awarded (based on the quality of report and presentation skill, participation in the question and answer session) by the examiners appointed by the University. ■

PROJECT WORK PHASE -2			
Course Code	20EPE41	CIE Marks	40
Number of contact Hours/Week	4	SEE Marks	60
Credits	20	Exam Hours	03

Course objectives:

- To support independent learning.
- To guide to select and utilize adequate information from varied resources maintaining ethics.
- To guide to organize the work in the appropriate manner and present information (acknowledging the sources) clearly.
- To develop interactive, communication, organisation, time management, and presentation skills.
- To impart flexibility and adaptability.
- To inspire independent and team working.
- To expand intellectual capacity, credibility, judgement, intuition.
- To adhere to punctuality, setting and meeting deadlines.
- To instil responsibilities to oneself and others.
- To train students to present the topic of project work in a seminar without any fear, face audience confidently, enhance communication skill, involve in group discussion to present and exchange ideas. ■

Project Work Phase - II: Each student of the project batch shall involve in carrying out the project work jointly in constant consultation with internal guide, co-guide, and external guide and prepare the project report as per the norms avoiding plagiarism. ■

Course outcomes:

At the end of the course the student will be able to:

- Present the project and be able to defend it.
- Make links across different areas of knowledge and to generate, develop and evaluate ideas and information so as to apply these skills to the project task.
- Habituated to critical thinking and use problem solving skills
- Communicate effectively and to present ideas clearly and coherently in both the written and oral forms.
- Work in a team to achieve common goal.
- Learn on their own, reflect on their learning and take appropriate actions to improve it. ■

Continuous Internal Evaluation:

Project Report: 20 marks. The basis for awarding the marks shall be the involvement of the student in the project and in the preparation of project report. To be awarded by the internal guide in consultation with external guide if any.

Project Presentation: 10 marks.

The Project Presentation marks of the Project Work Phase -II shall be awarded by the committee constituted for the purpose by the Head of the Department. The committee shall consist of three faculty from the department with the senior most acting as the Chairperson.

Question and Answer: 10 marks.

The student shall be evaluated based on the ability in the Question and Answer session for 10 marks.

Semester End Examination

SEE marks for the project report (30 marks), seminar (20 marks) and question and answer session (10 marks) shall be awarded (based on the quality of report and presentation skill, participation in the question and answer session) by the examiners appointed by the University. ■