Power Semiconductor Device & Components			
Course Code	24PEE12	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:2:0	SEE Marks	50
Credits	04	Exam Hours	03

Module-1

Introduction: Fabrication - Characteristics of Power Semiconductor devices, Conduction process in Semiconductors, PN Junctions, Charge control description of PN junction operation, Avalanche Breakdown.

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.

Diodes: Introduction, Basic structure and I-V Characteristics, Breakdown voltage considerations, On-State Losses, Switching Characteristics, Power Diode Types- General purpose Diodes, Fast recovery Diodes and Schottk-y diode ,Static & Dynamic performance, junction structure, Reverse recovery Characteristics, Snubber Circuit, Series — parallel operation, Spice-Diode Model.

Module-2

BJT: Introduction, Vertical Power Transistor structures, I-V characteristics, Physics of BJT Operations, Switching Characteristics, Breakdown voltages, Second breakdown, On-State losses, Types, Safe Operation Area (S.O.A) ,Switching Time, Base Drives Snubher Circuits, Power Darlington's Protection Circuits.

Module-3

MOSFETS: Introduction, Basic Structure, I-V characteristics, Physics of device Operations, Switching Characteristics, Operating Limitations & Types Principle of Operation, characteristics, SOA, Gate Drive Circuits, Spice model.

Module-4

IGBT: Introduction, Basic Structures, I-V characteristics, Physics of device Operations, Latchup in IGBTs , Switching Characteristics, Devise limits & SOA and Gate Driver Circuits, Comparison with MOSFETS and Power BJT, Junction Structure, Terminal Capacitance, Gate Driver Circuits, On-Off time, IGBT Spice modeling and simulation of the devices and circuits.

Module-5

THYRISTOR & FAMTLY DEVICES (Triac, GTO, LASCR): Introduction, Introduction, Basic Structure , I-V characteristics , Physics of device Operations, Switching Characteristics, Methods of Improving di/dt and dv/dt ratings, Gate Circuit consideration, Thyristor ratings and Protections, Snubber circuit, Heat sink design.

Emerging Devices – Introduction, Power Junction Field Effect Transistors, Field controlled Thyristors, JFET-Based devices versus other power devices, MOS-Controlled Thyristors, Power-Integrated Circuits, New Semiconductor materials for power devices.

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.

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.

- 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. 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 Electronics Converters - I			
Course Code	24PEE13	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	50
Credits	04	Exam Hours	03

Module-1

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-2

AC/AC Converters: Single-Phase AC/AC Voltage Converters - Time Proportional Control Three-PhaseConverters, 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.

AC Voltage Controllers: Principle of On-off Control, Principal of Phase control, single-phase, Three- phase AC voltage controllers, AC voltage controllers with PWM control, Design of AC Voltage controller circuits.

Module-3

Choppers: Principal of step down chopper with RL load, Principal of step up chopper, classification of choppers, Single, Multiquadrant operation of chopper with continuous/Discontinuous Modes, Thyristor chopper circuits.

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.

Module-4

Inverters: Single-Phase bridge inverters, three phase inverters with 180-Degree,120-Degree conduction, voltage control of single-phase and Three-phase inverters, advanced modulation techniques, harmonic reduction, VSI,CSI Voltage control, Three phase PWM Techniques, Performance parameters.

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-5

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:** Introduction to multilevel inverters, types of multilevel inverters, Diode clamped Multilevel inverter, Flying Capacitors multilevel Inverters, 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.
- 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 50.

- 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. 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.

3. Rashid M. H, Power Electronics – Circuits, Devices and Applications", 3 rd Edition Prentice Hall India, Second Edition, 2001.

HV – DC POWER TRANSMISSION			
Course Code	24PEE14	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Credits	03	Exam Hours	03

Module-1

Review of Power Transmission: Introduction, Comparison of AC and DC Transmission –Economics of Power Transmission, Technical performance and Reliability. Application of DC transmission ,Description of DC Transmission System, Types of DC links, Converter Station , Planning for HVDC Transmission ,Modern Trends in HVDC Technology ,Some operating Problems, HVDC Transmission based on Voltage source converters, Advantages and disadvantages, Problems of stability, corona, power loss. Insulation and co-ordination- economic consideration.

Module-2

Development of HVDC Technology: Historical development Technical details of existing system in operation in India and abroad, Advantages and limitations. Principle components different types HDVC system Types of converter circuits their comparison.

Line Commutated and voltage source converters: Introduction, Line commutated converter, Analysis of Graetz Bridge Neglecting Overlap, Choice of converter configuration for any pulse number, Analysis of 6 - pulse and 12 - pulse converters**:** Effects of source inductance, equivalent circuits and characteristics. Effect of finite smoothing reactor, Voltage source converter, Basic two level (Graetz Bridge) converter , A Three Level Voltage Source Converter, Pulse Width Modulation. Analysis of line commutated converter, LCC Bridge Characteristics, Characteristics of Twelve pulse converter, Detailed analysis of converters, Capacitor commutated converter, Analysis of voltage source converter.

Module-3

Converter and HVDC System Control: Introduction, Principles of DC Link Control , Converter control Characteristics, Basic Characteristics, Modification of control characteristics, System control Hierarchy, Firing Angle control, Current and extension angel control, starting and stopping of DC link, Power Control, Higher level controllers, Control of voltage source converters. Analogue and digital controllers, HVDC link, operation, compounding and regulation. Fault development and protection schemes, DC reactor and its design Consideration.

Converter Faults and Protection: Introduction, Converter faults, General, Communication Failure, Arc Through, Misfire, Current Extinction, Short circuit in a Bridge, Protection against over currents, Over voltages in a converter station, Surge arrestors, Protection against Over voltages, Protection against faults in a voltage source converter.

Module-4

Smoothing Reactor and DC Line: Introduction, Smoothing reactors, DC Line, Transient over Voltages in DC line, Protection of Dc Line DC Breakers, Monopolar operations, Effects of Proximity of AC and DC Transmission lines. Generations of Harmonics, Design of AC filters , Passive AC filters, DC Filters, Active Filters, Carrier frequency and RI Noise, Corona Effects, DC cables over voltages , Insulation coordination Potential applications of MTDC Systems, Types of MTDC systems, Control and Protection of MTDC Systems. MTDC Systems using Voltage source converters.

Module-5

Simulation of HVDC Systems: FACTS concept and General system Considerations- Reactive Power requirements in Steady state, sources of reactive power, SVC and STATCOM, Reactive power control during transients, Stability analyses of AC-DC inter connected systems, static VAR compensation. System Models- General, Converter Models , Model of converter controller, Modeling of DC network Modeling of ac network, Application of switching functions.

Course outcomes:

After completion of this Course, the student will be able to

1. Understand the complete operation of HVDC Converter stations
2. Understand the power flow control on HVDC Transmission system
3. Understand the Operation of the controller for HVDC in worst and normal operations
4. Analyze the AC / DC system interactions

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.

- 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. 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 /2018

Design of Power Converters.			
Course Code	24PEE15	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Credits	03	Exam Hours	03

Module-1

Introduction to power electronic systems, Power electronics versus Linear Electronics, Scope and Applications, Classification of Power Processors and converters, Interdisciplinary nature of Power electronics. Review of Basic Electrical and Magnetic Circuit Concepts. Power conditioners and Uninterruptible Power Supplies.

Module-2

Practical converter Design Considerations, Snubber Circuits, Functions and types of Snubber Circuits, Diode Snubbers, Snubber circuits for Thyristors, Turn-Off Snubber, Turn-On Snubber, Overvoltage Snubber.

Module-3

Gate and Base Drive Circuits : Preliminary Design Considerations, DC-Coupled Drive Circuits, Electricaly Isolated Drive Circuits, Cascode-Connected Drive Circuits, Thyristor Drive Circuits, Power Device Protection in Drive Circuits. Control Circuits of Resonant Converters - Integrated Circuit Family UCx861-8, Integrated Circuits for Control of Soft Switching PWM Converters.

Module-4

Protection of Devices and Circuits : Component Temperature Control and Heat Sinks, Magnetic core materials, core shapes, core sizes, core assembly and technology. Supply and load side Transients, Current Protections, Electromagnetic Interference.

Module-5

Design of Magnetic Components, Principles of Power Transformer Design, High frequency Transformer Design, Design of Current Transformers. Computer aided design of Transformers.

Course outcomes:

After completion of this Course, the student will be able to

1.

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.

- 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. Ned Mohan Tore. M. Undeland and William. P. Robbins; "Power Electronics: Converters, Applications and Design", 3rd Edition, John Wiley and Sons, 2003
2. G.C. Chryssis, "High frequency switching power supplies", McGraw Hill, 1989 (2nd Edn.)
3. Umanand. L. & Bhat. S.R. "Design of Magnetic Components for Switched Mode Power Converters", Wiley Eastern Publication, 1992.

Electrical Drives.			
Course Code	24PEE21	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Credits	04	Exam Hours	03

Module-1

Electrical Drives: Basic Elements of a Drive, Load Torque - Speed Characteristics, Stability of Drive Operations, Choice of Drives, Principle Factors affecting the choice of drive, Types of Electric Motor used in drives, Status of AC and DC Drives.

Dynamics of Electrical Drives- Fundamental Torque Equations, Speed Torque Conventions and Multiquadrant operations, Equivalent Values of Drive parameters, Components of Load Torques, Nature and Classification of Load Torques, Calculations of Time and Energy-Loss in Transients Operations. Steady State Stability, Load Equalization.

Control of Electrical Drives- Modes of Operations, Speed control and drives Classifications, Closed-Loop Control of Drives, Selection of Motor Power Rating- Thermal Model of Motor for Heating and Cooling, Classes of Motor Duty, Determination of Motor Rating

Module-2

DC DRIVES: Introduction, Basic characteristics of DC motors, Operating modes, Single-Phase drives, Three-Phase drives. Chopper drives: Principle of power control, Principle of regenerative and rheostatic brake control, Principle of Combined Regenerative and Rheostatic Brake Control, Single quadrant, two quadrants, and four quadrant chopper drives, Multiphase DC-DC Converters. Closed loop control of DC Drives. Chopper Controlled DC Drives, Chopper Control of Separately Exited DC Motor, Chopper Control of Series Motor, Source Current Harmonics in Choppers and Converter Ratings.

Module-3

Induction motor drives, performances characteristic's, stator voltage control, rotor voltage control, frequency control, voltage & frequency control, current control, voltage current & frequency control. Three Phase Induction Motors, Operation with Unbalanced Source Voltages and Single Phasing, Operation with Unbalanced Rotor Impedances.

Module-4

Analysis of Induction Motor Fed from Non-Sinusoidal Voltage supply, starting, Braking, Transient Analysis, speed Control, Pole Changing, Pole Amplitude Modulation, Stator Voltage Control, Variable Frequency Control from Voltage Sources, VSI Control, Cycloconverter control, Closed loop speed control and Converter Rating For VSI and Cycloconverter Induction motor Drives, Variable Frequency Control from Current Sources, CSI Control , VSI & CSI fed induction motor drive system, Current Regulated VSI Control, Eddy current Drives. Single Phase Induction Motor, Starting Methods and types. Braking and Speed control of single Phase Induction Motor.

Module-5

Brushless DC Motors, Stepper, Variable reluctance Motors, Static excitation Schemes of AC generators. Solar and Battery Powered Drives- Solar panels, Motors Suitable For Pump Drives, Solar Powered Pump drives, Battery Powered Vehicles, Solar-Powered Electrical Vehicles and Boats. Energy Conversion In Electric Drives – Losses in electric Drive system, Measures for Energy conversion in Electric Drives, Use Of Efficient Semiconductor Converters , Use Of Efficient Motors, Use Of Variable Speed Drives , Energy Efficient Operation Of Drives, Improvement of Power Factor, Using a Motor of Right rating, Improvement of quality of supply, Use of single-three phase semiconductor Converters in Rural Applications, Regular & Preventive maintenance of Motors, Transformers and Coupled Equipments. Electrical Drive Systems and components Used for Obtaining signals for Interlocking, Sequence Operations & Protection.

Course outcomes:

After completion of this 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 50.

- 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. Gopal K Dubey, Fundamentales of Electrical Drives. Narosa Publishing House.

2. M.H.Rashid power electronics circuits, devices and applications 3rd editions PHI Publications

3. Murphy JMD Thyristor control of AC motors Pegamon press 1973.

4. DE.N.K. & Sen.P.K. Electric Drives, PHI Publishers.

Power Electronics Converters - II			
Course Code	22PEE22	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Credits	03	Exam Hours	03

Module-1

Introduction to switching DC power supplies, linear power supplies and switch mode DC power supplies. DC- DC Converters - Principle of operation of buck converters, boost converters, buck-boost converters with continuous conduction mode, boundary between continuous and discontinuous conduction, discontinuous –conduction mode of operation and their equations & analysis.

Module-2

Principle of operation of Cuk converters, fly back converters, forward converters, push-pull converters, half bridge and full bridge converters, isolated Cuk Converters and their analysis. Input & output filter design, need of regulated output, isolation and multi-output operation of isolated converters, MMF equations.

Module-3

Introduction to Resonant converters: Zero-voltage and/or zero-current switching's. Classification of resonant converters, basic resonant circuit concepts, load resonant converters, resonant switch converters, zero-voltage-switching's, clamped-voltage topologies, resonant-dc-link inverters with zero-voltage switchings, high-frequency-link integral-half-cycle converters.

Module-4

Introduction to magnetic materials, magnetic materials for Cores, core shapes, sizes, assembly and technology. Design of inductors and its procedures. Hysteresis loss and eddy current loss in laminated cores, skin effect. Power line disturbances, power conditioners, uninterruptible power supplies.

Module-5

Principles of power transformer design, high frequency transformers design. Computer aided design of transformers. Design of current transformers.

Course outcomes:

After completion of this Course, the student will be able to

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.

- 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

4. Ned Mohan Tore. M. Undeland and William. P. Robbins; "Power Electronics: Converters, Applications and Design", 3rd Edition, John Wiley and Sons, 2003
5. G.C. Chryssis, "High frequency switching power supplies", McGraw Hill, 1989 (2nd Edn.)
6. Umanand. L. & Bhat. S.R. "Design of Magnetic Components for Switched Mode Power Converters", Wiley Eastern Publication, 1992.

POWER QUALITY ISSUES AND MITIGATION			
Course Code	24PEE23	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	50
Credits	03	Exam Hours	03

Module - I

Introduction: Introduction to power quality, interest in power quality, power quality, voltage quality, overview of power quality phenomena, power quality and EMC standard.

Module - II

Long Interruptions and Reliability Evaluation: Introduction, observation of system performance, standards and regulations, overview of reliability evaluation, reliability evaluation techniques, cost of interruptions, comparison of observation and reliability evaluation, examples.

Short Interruptions: Introduction, terminology, origin of short interruptions, monitoring of short interruptions, influence on equipment, single phase tripping, stochastic prediction of short interruptions.

Module - III

Voltage Sags - Characterization**:** Introduction, voltage sag magnitude, voltage sag duration, three phase unbalance, phase angle jumps, magnitude and phase angle jumps for three phase unbalanced sags, other characteristic of voltage sags, load influence on voltage sags, sag due starting of induction motors.

Module - IV

Voltage Sags – Equipment Behavior: Introduction to voltage sags equipment behavior, computers and consumer electronics, adjustable speed AC drives, adjustable speed DC drives, other sensitive load.

Module - V

Mitigation of Interruptions and Voltage Sags: Overview of mitigation methods, power system design – redundancy throug switching and parallel operation, system equipment interface.

Course outcomes:

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

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.

- 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.

REFERENCE BOOKS

1. Math H J Bollen, "Understanding Power Quality Problems; Voltage Sags and Interruptions", Wiley India, 2011.
2. Roger C Dugan, et.el, "Electrical Power Systems Quality", 2nd Edition, TMH, 2011.
3. G T Heydt, "Electric Power Quality", Stars in Circle publications, 1991.
4. Ewald F Fuchs, et.el, "Power Quality in Power System and Electrical Machines", Academic Press, Elsevier.

Solid State AC Motor Controllers			
Course Code	24PEE241	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Credits	03	Exam Hours	03

Module-1

Introduction, induction machines, rotating magnetic field, torque production, equivalent circuit, torque – speed curves, variable-voltage, constant – frequency operation, variable frequency operation, constant volts/ Hz operation, drive operating regions, variable stator current operation, effect of harmonics. Dynamics d-q model, wound field machines.

Module-2

Speed control of 3-phase Induction motors by AC Power controllers-Static Rotor Resistance control, slip energy recovery schemes- Static Kramer Drive – static Scherbius drive – Closed loop control schemes using the above special control techniques.

Module-3

Speed control of 3- phase induction motors using Voltage Source Inverters, Current Source Inverters. Speed Control of 3 – phase induction motors by Vector Control methods-Basic concepts of Direct and indirect methods of control performance and analysis of induction motors with non – sinusoidal supply sources.

Module-4

Speed control of Synchronous motor – Self Controlled and Separately Controlled Synchronous motors. Self controlled and Synchronous motor. CSI fed , Cyclo – Converter fed, Speed control and performance of Synchronous motor using a variable frequency supply with D.C. link Inverter. Comparative study of various methods of speed control of synchronous motors.

Module-5

VSI fed synchronous motor drive – steady state operation –methods of control – operation with field weakening. Solid state drive systems for Brushless DC motor, Stepper motor and Switched reluctance motors.

Course outcomes:

After completion of this Course, the student will be able to

1. Understand the Operation and Control of AC Drives
2. Model and Simulate the AC Drives.
3. Analyze different Scalar Control Methods
4. Analyze the current Fed Inverter control methods.
5. Analyze the equations governing the Vector Control.

Question paper pattern:

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.

- 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. Vedam Subramanyam, Thyristor Control of Electric Drives, Tata McGraw Hill, 1988.
2. B.K.Bose, Power Electronics and AC drives, Prentice Hall, 1986.
3. Gopal K Dubey, Fundamentales of Electrical Drives. Narosa Publishing House.

HYBRID ELECTRIC VEHICLES			
Course Code	24PEE242	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Credits	03	Exam Hours	03

Module - I

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 - II

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 - III

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 - IV

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 - V

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 technologiesand 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 50.

- 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.

REFERENCE BOOKS

1. Hybrid Electric Vehicles principles and Applications with Practical Perspectives, Chris Mi,M. Abul asrur, David Wenzhong Gao, Wiley, 2011.
2. Modern Electric, Hybrid Electric and Fuel Cell Vehicles – Fundamentals, Theory and Design – MehrdadEhsani, UiminGao and Ali Emadi - Second Edition - CRC Press, 2010.
3. Electric Vehicle Technology Explained - James Larminie, John Lowry - John Wiley & Sons Ltd, - 2003.
4. Electric Vehicle Battery Systems - SandeepDhameja – Newnes - New Delhi – 2002.

FACTS CONTROLLERS			
Course Code	22PEE243	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Credits	03	Exam Hours	03

Module-1

Introduction to facts: Review of basics of power transmission networks-control of power flow in AC transmission line- Analysis of uncompensated AC Transmission linePassive reactive power compensation: Effect of series and shunt compensation at the mid-point of the line on power transfer- Need for FACTS controllers- types of FACTS controllers.

Module-2

Static Var Compensator (SVC) Configuration of SVC- voltage regulation by SVCModeling of SVC for load flow analysis- Modeling of SVC for stability studies-Design of SVC to regulate the mid-point voltage of a SMIB system- Applications: transient stability enhancement and power oscillation damping of SMIB system with SVC connected at the mid-point of the line. Thyristor controlled series capacitors (TCSC) - Concepts of Controlled Series Compensation – Operation, modeling, analysis and control of TCSC.

Module-3

Voltage source converter based FACTS controllers: Static synchronous compensator (STATCOM)- Static synchronous series compensator (SSSC)- Operation of STATCOM and SSSC-Power flow control with STATCOM and SSSC- Modeling of STATCOM and SSSC for power flow and transient stability studies; of Unified Power Flow Controllers(UPFC) - Modeling, Operation and control.

Module-4

Static Voltage and Phase Angle Regulators: Power flow control, TCVR and TCPAR, improvement of transient stability with these. GCSC _ operation, modeling and analysis. Comparison with TCSC IPFC – Block diagram, operation and comparison with UPFC.

Module-5

Controllers and their co-ordination: Location of FACTS devices, Controller interactions – SVC–SVC interaction - co-ordination of multiple controllers using linear control techniques – Quantitative treatment of control coordination.; Coordination of FACTS with HVDC links.

Course outcomes:

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

1. Analyze, model and describe operation of different FACTS devices.
2. Select and Design FACTS device for a given system.
3. Design controller for various FACTS devices.
4. Analyze the interaction between different FACTS devices and HVDC links

Question paper pattern:
The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.

- 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.

CYBERSECURITY IN THE ELECTRICITY SECTOR			
Course Code	24PEE244	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
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 50.

- 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

UNINTERRUPTIBLE POWER SUPPLY			
Course Code	24PEE251	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Credits	03	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 50.

- 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.

DIGITAL POWER ELECTRONICS			
Course Code	24PEE252	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Credits	03	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 50.

- 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.

EMC IN POWER ELECTRONICS			
Course Code	24PEE253	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
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 50.

- 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.

INTERNET-BASED CONTROL SYSTEMS			
Course Code	24PEE254	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Credits	03	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 50.

- 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.