VISVESVARAYA TECHNOLOGICAL UNIVERSITY
BELAGAVI

Scheme of Teaching and Examination and Syllabus
M.Tech POWER EECRTONICS (EPE)

Eligibility: Bachelor's degree in Engineering or Technology in
(a)Electrical and Electronics Engineering (b) Electronics and Communication Engineering
(c) Electronics and Telecommunication Engineering (d) Telecommunication Engineering
(e) Electronics and Instrumentation Engineering (f) Instrumentation Engineering
(g) Biomedical Engineering (h) Medical Electronics (i) AMIE in appropriate branch
(i) GATE: EC, IT, EE

(Effective from Academic year 2016-17)

BOARD OF STUDIES IN ELECTRICAL AND ELECTRONICS ENGINEERING

December 2016

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI

SCHEME OF TEACHING AND EXAMINATION - 2016-17

M.Tech POWER EECRTONICS (EPE)

CHOICE BASED CREDIT SYSTEM (CBCS)

(Total number of credits prescribed for the programme - 85)

I SEMESTER

Sl. No	Course Code	Title	Teaching Hours /Week		Examination				Credits
			Theory	Practical/ Field work/ Assignment	Duration in hours	I.A. Marks	Theory/ Practical Marks	Total Marks	
1	16EEE11	Applied Mathematics	04	--	03	20	80	100	4
2	16EPE12	Power Semiconductor Devices and Components	04	--	03	20	80	100	4
3	16EPE13	Power Electronic Converters	04	--	03	20	80	100	4
4	16EPE14	Modelling and Design of Controllers	04	--	03	20	80	100	4
5	16EPE15X	Elective -1	03	--	03	20	80	100	3
6	16EPEL16	Power Electronics Laboratory - 1	-	3	03	20	80	100	2
7	16EPE17	Seminar	-	3	-	100	-	100	1
TOTAL			**19**	**06**	**18**	**220**	**480**	**700**	**22**

Number of credits completed at the end of I semester: 22

Elective - 1

Course Code under 16EPE15X	Title
16EPE151	Embedded Systems
16EPE152	Power System Harmonics
16EPE153	Advanced Control Systems
16EPE154	EMC in Power Electronics

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SCHEME OF TEACHING AND EXAMINATION - 2016-17

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CHOICE BASED CREDIT SYSTEM (CBCS)

(Total number of credits prescribed for the programme - 85)

II SEMESTER

Sl. No	Course Code	Title	Teaching Hours /Week		Examination				Credits
			Theory	Practical/ Field work/ Assignment	Duration in hours	I.A. Marks	Theory/ Practical Marks	Total Marks	
1	16EPE21	Electric Drives	04	--	03	20	80	100	4
2	16EPE22	Switched - Mode Power Supplies	04	--	03	20	80	100	4
3	16EPE23	Modelling and Analysis of Electrical Machines	04	--	03	20	80	100	4
4	16EPE24	FACTS Controllers	04	--	03	20	80	100	4
5	16EPE25X	Elective - 2	03	--	03	20	80	100	3
6	16EPEL26	Power Electronics Laboratory - 2	-	3	03	20	80	100	2
7	16EPE27	Seminar	-	3	-	100	-	100	1
TOTAL			**19**	**06**	**18**	**220**	**480**	**700**	**22**

Number of credits completed at the end of II semester: 22+ 22 = 44

Elective - 2

Course Code under 16EPE25X	Title
16EPE251	Converters for Solar and Wind Power Systems
16EPE252	Uninterruptible Power Supply
16EPE253	Power Quality Problems and Mitigation
16EPE254	Hybrid Electric Vehicles

Note: Project Phase-1: 6-week duration shall be carried out between 2nd and 3rd Semester vacation. Candidates in consultation with the guide shall carry out literature survey/ visit industries to finalize the topic of Project.

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI
SCHEME OF TEACHING AND EXAMINATION - 2016-17
M.Tech POWER EECRTONICS (EPE)
CHOICE BASED CREDIT SYSTEM (CBCS)
(Total number of credits prescribed for the programme - 85)

III SEMESTER

<table>
<tr><th rowspan="2">Sl. No</th><th rowspan="2">Course Code</th><th rowspan="2">Title</th><th colspan="2">Teaching Hours /Week</th><th colspan="4">Examination</th><th rowspan="2">Credits</th></tr>
<tr><th>Theory</th><th>Practical/ Field work/ Assignment</th><th>Duration in hours</th><th>I.A. Marks</th><th>Theory/ Practical Marks</th><th>Total Marks</th></tr>
<tr><td>1</td><td>16EPE31</td><td>Seminar / Presentation on Internship.
(After 8 weeks from the date of commencement)</td><td></td><td></td><td>--</td><td>25</td><td>--</td><td>25</td><td rowspan="3">20</td></tr>
<tr><td>2</td><td>16EPE32</td><td>Report on Internship</td><td>--</td><td>--</td><td>--</td><td>25</td><td>--</td><td>25</td></tr>
<tr><td>3</td><td>16EPE33</td><td>Evaluation and Viva-Voce of Internship</td><td>--</td><td>--</td><td>--</td><td>--</td><td>50</td><td>50</td></tr>
<tr><td>4</td><td>16EPE34</td><td>Evaluation of Project phase -1</td><td>--</td><td>--</td><td>--</td><td>50</td><td>--</td><td>50</td><td>1</td></tr>
<tr><td colspan="3">TOTAL</td><td>--</td><td>--</td><td>--</td><td>100</td><td>50</td><td>150</td><td>21</td></tr>
</table>

Number of credits completed at the end of III semester: 22+ 22 + 21 = 65

Note:
Internship of 16 weeks shall be carried out during III semester.
Major part of the Project work shall also be carried out during the III semester in consultation with the Guide/s.

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI

SCHEME OF TEACHING AND EXAMINATION - 2016-17

M.Tech POWER EECRTONICS (EPE)

CHOICE BASED CREDIT SYSTEM (CBCS)

(Total number of credits prescribed for the programme - 85)

IV SEMESTER

Sl. No	Course Code	Title	Teaching Hours /Week		Examination				Credits
			Theory	Practical/ Field work/ Assignment	Duration in hours	I.A. Marks	Theory/ Practical Marks	Total Marks	
1	16EPE41	HVDC power Transmission	04	--	03	20	80	100	4
2	16EPE42X	Elective - 3	03	--	03	20	80	100	3
3	16EPE43	Evaluation of Project phase - 2	--	--	--	50	-	50	3
4	16EPE44	Evaluation of Project and Viva-Voce	--	--	--	--	100 + 100	200	10
TOTAL			**07**	**--**	**06**	**90**	**360**	**450**	**20**

Number of credits completed at the end of IV semester: 22+ 22 + 21 + 20 = 85

Elective - 3

Course Code under 16EPE42X	Title
16EPE421	Digital Power Electronics
16EPE422	MPPT in Solar Systems
16EPE423	Multi-Terminal DC Grids
16EPE424	Multilevel Converters for Industrial Applications

Note: 1. Project Phase-1: 6-week duration shall be carried out between 2nd and 3rd Semester vacation. Candidates in consultation with the guide shall carry out literature survey/ visit industries to finalize the topic of Project.

2. Project Phase-2: 16-week duration during 4th semester**.** Evaluation shall be done by the committee comprising of HoD as Chairman, Guide and Senior faculty of the department.

3.**Project Evaluation**: Evaluation shall be taken up at the end of 4th semester. Project work evaluation and Viva-Voce examination shall conducted

4**. Project evaluation:**

a. Internal Examiner shall carry out the evaluation for 100 marks.

b. External Examiner shall carry out the evaluation for 100 marks.

c .The average of marks allotted by the internal and external examiner shall be the final marks of the project evaluation.

d. Viva-Voce examination of Project work shall be conducted jointly by Internal and External examiner for 100 marks.

M.TECH POWER ELECTRONICS (EPE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - I			
APPLIED MATHAMATICS (Core Course)			
Course Code	16EEE11	IA Marks	20
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	Exam Marks	80
Credits - 04			

Course objectives:

- The objectives of this course is to acquaint the students with principles of advanced mathematics through linear algebra, transform methods for differential equations, calculus of variations and linear and non-linear programming, that serve as an essential tool for applications of electrical engineering sciences. ■

Module-1		Teaching Hours
Numerical Methods: Solution of algebraic and transcendental equations- iterative methods based on second degree equation – Muller method(no derivation), Chebyshev method. Fixed point iteration method (first order), acceleration of convergence- Δ^2 - Aitken's method. System of non-linear equations – Newton-Raphson method. Complex roots by Bairstow's method.■		**10**
Revised Bloom's Taxonomy Level	L_2 – Understanding, L_3 – Applying	
Module-2		
Numerical Solution of Partial Differential Equations: Classification of second order equations, parabolic equations-solution of one dimensional heat equation, explicit method, Crank-Nicolson method. Hyperbolic equations- solution of one dimensional wave equation and two-dimensional Laplace equation by explicit method. ■		**10**
Revised Bloom's Taxonomy Level	L_3 – Applying	
Module-3		
Linear Algebra: Vector spaces, linear dependent, independence, basis and dimension, elementary properties, examples. **Linear Transformations**: Definition, properties, range and null space, rank and nullity, algebra of linear transformations-invertible, singular and non-singular transformations, representation of transformations by matrices.■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding	
Module-4		
System of linear algebraic equations and Eigen value problems: Iterative methods - Gauss-Seidal method, SOR method, Eigen value problems – Gerschgorian circle theorem, Eigen values and Eigen vectors of real symmetric matrices -Jacobi method. **Interpolation:** Hermite interpolation, spline interpolation, numerical solution of differential equations – Numerov method. ■		**10**
Revised Bloom's Taxonomy Level	L_3 – Applying	
Module-5		
Optimization: Linear programming- formulation of the problem, general linear programming problem, simplex method, artificial variable technique, Big M-method. **Graph Theory:** Basic terminologies, types of graphs, sub graphs, graphs isomorphism, connected graphs-walks, paths, circuits, connected and disconnected graphs, operations on graphs, Eulerian paths and circuits, Hamiltonian paths and circuits, applications to electrical circuits. ■		**10**
Revised Bloom's Taxonomy Level	L_3 – Applying, L_4 – Analysing.	

M.TECH POWER ELECTRONICS (EPE)
16EEE11 APPLIED MATHAMATICS (Core Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Course outcomes:

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

1. Employ numerical techniques in order to achieve more accurate values in the computation of roots of algebraic and non-linear equations.
2. Utilize analytical and numerical schemes to solve partial differential equations applicable to engineering problems.
3. Understand vector spaces, basis, linear transformations and the process of obtaining matrix of linear transformations arising in magnification and rotation of images.
4. Apply standard iterative methods to compute Eigen values and solve ordinary differential equations.
5. Employ linear and non-linear programming techniques in simulation of network systems and optimization of electrical circuits. ■

Graduate Attributes (As per NBA):

Critical Thinking, Problem Solving, Research Skill, Usage of Modern Tools.

Question paper pattern:

- The question paper will have ten full questions carrying equal marks.
- Each full question is for 16 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions 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	Linear Algebra and its Applications	David C.Lay et al	Pearson	5th Edition,2015
2	Numerical methods in Engineering and Science (with C, C++ & MATLAB)	B.S.Grewal	Khanna Publishers	2014
3	Graph Theory with Applications to Engineering and Computer Science	Narsingh Deo	PHI	2012
4	Numerical Methods for Scientific and Engineering Computation	M. K. Jain et al	New Age International	9th Edition, 2014
5	Higher Engineering Mathematics	B.S. Grewal	Khanna Publishers	43rd Edition,2015
6	Linear Algebra	K.Hoffman et al	PHI	2011
7	**Web links:**1. http://nptel.ac.in/courses.php?disciplineId=111 2. http://www.class-central.com/Course/math(MOOCs) 3.www.wolfram.com			

<table>
<tr><td colspan="4">M.TECH POWER ELECTRONICS (EPE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - I</td></tr>
<tr><td colspan="4">POWER SEMICONDUCTOR DEVICES AND COMPONETS (Core Course)</td></tr>
<tr><td>Course Code</td><td>16EPE12</td><td>IA Marks</td><td>20</td></tr>
<tr><td>Number of Lecture Hours/Week</td><td>04</td><td>Exam Hours</td><td>03</td></tr>
<tr><td>Total Number of Lecture Hours</td><td>50</td><td>Exam Marks</td><td>80</td></tr>
<tr><td colspan="4">Credits - 04</td></tr>
</table>

Course objectives:

- To enhance the knowledge of fundamentals of semiconductor physics, power electronics and power computation in circuits
- To enhance the knowledge of fundamentals of various semiconductor devices, their operation and characteristics.
- To explain the design and operation of drive circuits and snubber circuits.
- To explain the controlling of temperature rise of the semiconductor devices and designing of magnetic components used for the power electronic circuits. ■

Module-1	Teaching Hours
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. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	
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. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	
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. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	

M.TECH POWER ELECTRONICS (EPE)
16EPE12 POWER SEMICONDUCTOR DEVICES AND COMPONETS (Core Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-4		**Teaching Hours**
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 ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge Problem, Analysis, Design / development of solutions, Ethics.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text/Reference Books

1	Power Electronics	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

M.TECH POWER ELECTRONICS (EPE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - I			
POWER ELECTRONIC CONVERTERS (Core Course)			
Course Code	16EPE13	IA Marks	20
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	Exam Marks	80
Credits - 04			

Course objectives:

- To impart knowledge of PWM techniques in controlling the converter operation.
- To impart knowledge of designing and analyzing DC – DC PWM converters and control modules.
- To impart knowledge of designing and analyzing DC – AC and AC – DC converters.
- To impart knowledge of analyzing different types of resonant converters and their control.
- To impart knowledge of AC –AC converters and multilevel controllers. ■

Module-1		Teaching Hours
PWM DC/DC Converters: Forward Converters - Analysis of the Basic Circuit, Galvanically Isolated Forward Converter, Boost Converter - Analysis of the Basic Scheme, Variation of the Output Voltage, Boundary Between the Continuous and the Discontinuous Mode , Discontinuous Mode Power Losses, Indirect Converter - Boundary Between the Continuous and the Discontinuous Mode, Discontinuous Mode, Indirect Converter with Galvanic Separation, Push – Pull (Symmetric) Converters - Analysis of Idealized Circuit in Continuous Mode, Output Characteristics, Selection of Components, DC Premagnetization of the Core, Half-Bridge Converter, Bridge Converter, Hamilton Circuit, Ćuk Converters - Elimination of the Current Ripple, Ćuk Converters with Galvanic Isolation. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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.■		**10**
Revised Bloom's Taxonomy Level	L_2 – Understanding, L_3 – Applying, L_4 – Analysing, L_5 – Evaluating.	

M.TECH POWER ELECTRONICS (EPE)
16EPE13 POWER ELECTRONIC CONVERTERS (Core Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-4		Teaching Hours
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem analysis.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text/Reference Books

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

M.TECH POWER ELECTRONICS (EPE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - I

MODELLING AND DESIGN OF CONTROLLERS (Core Course)

Course Code	16EPE14	IA Marks	20
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	Exam Marks	80

Credits - 04

Course objectives:

- To impart knowledge required for modeling and computer simulation of power electronic converters and systems.
- To explain control system essentials in representing system in digital domain.
- To explain the designing of digital controllers by different methods.
- To explain the design and analysis of optimal and robust controllers by different methods.
- To impart knowledge of discrete computation essentials. ■

Module-1		Teaching Hours
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

M.TECH POWER ELECTRONICS (EPE)
16EPE14 MODELLING AND DESIGN OF CONTROLLERS (Core Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-5		**Teaching Hours**
Discrete Computation Essentials: Numeric Formats, Tracking the Base Point in the Fixed Point System, Normalization And Scaling, Arithmetic Algorithms. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Design / development of solutions, Ethics.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text/Reference Books

1	Power Electronics Converters, 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

M.TECH POWER ELECTRONICS (EPE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - I			
EMBEDDED SYSTEMS (Elective Course)			
Course Code	16EPE151	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80
Credits - 03			

Course objectives:

- To impart knowledge of embedded systems with suitable examples, explanation of process, classification of embedded systems.
- To explain the processor architecture, memory organization, communication with processor and interrupt services.
- To explain the program modeling concepts, inter-process communication and synchronization of processes. ■

Module-1	Teaching Hours
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.■	**08**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	
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. ■	**08**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	
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.■	**08**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	
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. ■	**08**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	

M.TECH POWER ELECTRONICS (EPE)
16EPE151 EMBEDDED SYSTEMS (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-5		**Teaching Hours**
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

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.■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem analysis.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text Book

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

<table>
<tr><td colspan="4">M.TECH POWER ELECTRONICS (EPE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - I</td></tr>
<tr><td colspan="4">POWER SYSTEM HARMONICS (Elective Course)</td></tr>
<tr><td>Course Code</td><td>16EPE152</td><td>IA Marks</td><td>20</td></tr>
<tr><td>Number of Lecture Hours/Week</td><td>03</td><td>Exam Hours</td><td>03</td></tr>
<tr><td>Total Number of Lecture Hours</td><td>40</td><td>Exam Marks</td><td>80</td></tr>
<tr><td colspan="4">Credits - 03</td></tr>
</table>

Course objectives:

- To explain about different sources of harmonics in power system.
- To explain effects of harmonics and mitigation of harmonics.
- To explain modeling of power system components for harmonic studies.
- Introducing different methods of harmonic studies. ■

<table>
<tr><td colspan="2">Module-1</td><td>Teaching Hours</td></tr>
<tr><td colspan="2">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. ■</td><td rowspan="2">08</td></tr>
<tr><td>Revised Bloom's Taxonomy Level</td><td>L₁ – Remembering, L₂ – Understanding.</td></tr>
<tr><td colspan="3">Module-2</td></tr>
<tr><td colspan="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. ■</td><td rowspan="2">08</td></tr>
<tr><td>Revised Bloom's Taxonomy Level</td><td>L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analysing.</td></tr>
<tr><td colspan="3">Module-3</td></tr>
<tr><td colspan="2">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. ■</td><td rowspan="2">08</td></tr>
<tr><td>Revised Bloom's Taxonomy Level</td><td>L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analysing.</td></tr>
<tr><td colspan="3">Module-4</td></tr>
<tr><td colspan="2">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. ■</td><td rowspan="2">08</td></tr>
<tr><td>Revised Bloom's Taxonomy Level</td><td>L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analysing.</td></tr>
<tr><td colspan="3"></td></tr>
</table>

M.TECH POWER ELECTRONICS (EPE) 16EPE152 POWER SYSTEM HARMONICS (Elective Course) (continued) CHOICE BASED CREDIT SYSTEM (CBCS)		
Module-5		**Teaching Hours**
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Design / development of solutions, Modern Tool Usage, Ethics.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text/Reference Books

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

M.TECH POWER ELECTRONICS (EPE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - I			
ADVANCED CONTROL SYSTEMS (Elective Course)			
Course Code	16EPE153	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80
Credits - 03			

Course objectives:

- To impart basic knowledge about digital control through signal conversion, their representation, z – transform, stability analysis in the z – plane, signal reconstruction .etc.
- Development of models of systems in the digital domain, and their implementation.
- To perform state variable method of analysis of digital control systems.
- To impart knowledge of optimal control system analysis in continuous and discrete time domains.
- To impart knowledge about the analysis of nonlinear control systems. ■

Module-1		**Teaching Hours**
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

M.TECH POWER ELECTRONICS (EPE)
16EPE153 ADVANCED CONTROL SYSTEMS (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-5		**Teaching Hours**
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Design / development of solutions, Modern Tool Usage, Ethics.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text/Reference Books

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

M.TECH POWER ELECTRONICS (EPE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - I

EMC IN POWER ELECTRONICS (Elective Course)

Course Code	16EPE154	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80

Credits - 03

Course objectives:

- To explain different electromagnetic disturbances and their classification.
- To explain measurement of the high frequency characteristics of EMI filter elements, their selection and measurement.
- To explain suppression of noise in relay systems.
- To explain designing and analysis of EMI filters.
- To explain conduction of test as per IEC specifications and reducing internal EMI. ■

Module-1		Teaching Hours
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
Module-2		
EMI Filter Elements: Measuring High Frequency Characteristics OF EMI Filter Elements, Capacitors, Choke Coils, Resistors. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

M.TECH POWER ELECTRONICS (EPE)
16EPE154 EMC IN POWER ELECTRONICS (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Design / development of solutions, Modern Tool Usage, Ethics.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text Book

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

M.TECH POWER ELECTRONICS (EPE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - I

POWER ELECTRONIS LABORATORY-1

Course Code	16EPEL16	IA Marks	20
Number of Practical Hours/Week	03	Exam Hours	03
Total Number of Practical Hours	40	Exam Marks	80

Credits - 02

Course objectives:

- To conduct experiment on various power electronic devices to analyze their static and dynamic characteristics.
- To conduct experiments and enhance understanding of different power electronic converters. ■

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.

Revised Bloom's Taxonomy Level	L_3 – Applying, L_4 – Analysing, L_5 – Evaluating, L_6 – Creating

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Conduct investigations of complex Problems, Modern Tool Usage, Individual and Team work, Communication.

M.TECH POWER ELECTRONICS (EPE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - I			
SEMINAR			
Course Code	16EPE17	IA Marks	100
No. of Lecture Hours/Week	--	Exam Hours	--
Number of contact Hours/week	03	Number of Tutorial Hours/week	--
Total No. of contact Hours	--	Exam Marks	--
Credits - 01			

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, 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 Internal Assessment 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 Chairman. ■

Marks distribution for internal assessment of the course 16EPE17 seminar:
Seminar Report: 30 marks
Presentation skill:50 marks
Question and Answer:20 marks

Graduate Attributes (As per NBA):
Engineering Knowledge, Problem Analysis, Design / development of solutions, Conduct investigations of complex Problems, Modern Tool Usage, Engineers and society, Environment and sustainability, Ethics, Individual and Team work, Communication.

*** END ***

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI

SCHEME OF TEACHING AND EXAMINATION - 2016-17

M.Tech POWER EECRTONICS (EPE)

CHOICE BASED CREDIT SYSTEM (CBCS)

(Total number of credits prescribed for the programme - 85)

II SEMESTER

Sl. No	Course Code	Title	Teaching Hours /Week		Examination				Credits
			Theory	Practical/ Field work/ Assignment	Duration in hours	I.A. Marks	Theory/ Practical Marks	Total Marks	
1	16EPE21	Electric Drives	04	--	03	20	80	100	4
2	16EPE22	Switched - Mode Power Supplies	04	--	03	20	80	100	4
3	16EPE23	Modelling and Analysis of Electrical Machines	04	--	03	20	80	100	4
4	16EPE24	FACTS Controllers	04	--	03	20	80	100	4
5	16EPE25X	Elective - 2	03	--	03	20	80	100	3
6	16EPEL26	Power Electronics Laboratory - 2	-	3	03	20	80	100	2
7	16EPE27	Seminar	-	3	-	100	-	100	1
TOTAL			**19**	**06**	**18**	**220**	**480**	**700**	**22**

Number of credits completed at the end of II semester: 22+ 22 = 44

Elective - 2

Course Code under 16EPE25X	Title
16EPE251	Converters for Solar and Wind Power Systems
16EPE252	Uninterruptible Power Supply
16EPE253	Power Quality Problems and Mitigation
16EPE254	Hybrid Electric Vehicles

Note: Project Phase-1: 6-week duration shall be carried out between 2nd and 3rd Semester vacation. Candidates in consultation with the guide shall carry out literature survey/ visit industries to finalize the topic of Project.

M.TECH POWER ELECTRONICS (EPE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - II			
ELECTRIC DRIVES (Core Course)			
Course Code	16EPE21	IA Marks	20
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	Exam Marks	80
Credits - 04			

Course objectives:

- To give an introduction to drive, their characteristics and breaking.
- To explain the basic elements of drives, classification of drives, their dynamics and speed control
- To explain selection of drive for a specific application.
- To explain control of an electric drive using microprocessor. ■

Module-1		Teaching Hours
Characteristics Electric motors: Introduction, Characteristics of DC motors, Three phase Induction Motors and Synchronous Motors, Braking of Electric Motors.■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

M.TECH POWER ELECTRONICS (EPE)
16EPE21 ELECTRIC DRIVES (Core Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text Book

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

M.TECH POWER ELECTRONICS (EPE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - II

SWITCHED - MODE POWER SUPPLIES (Core Course)

Course Code	16EPE22	IA Marks	20
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	Exam Marks	80

Credits - 04

Course objectives:

- To give an overview on SMPS, its characteristics, new technologies, basic principles and control modes.
- To introduce the topology of DC/DC converter used and the method of selecting key peripheral components of SMPS.
- To explain the power factor correction circuit design of SMPS, the design of high-frequency transformer, the examples of SMPS optimization design, and the key design points of SMPS.
- To introduce the SMPS testing technology and the protection circuit design of SMPS. ■

Module-1	Teaching Hours
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. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	
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. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	
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. ■	**10**
Revised Bloom's Taxonomy Level: L_1 - Remembering, L_2 - Understanding, L_3 – Applying.	

M.TECH POWER ELECTRONICS (EPE)
16EPE22 SWITCHED - MODE POWER SUPPLIES (Core Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-4		Teaching Hours
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

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.■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Design / development of solutions, Ethics, Communication.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text Book

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

M.TECH POWER ELECTRONICS (EPE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - II

MODELLING AND ANALYSIS OF ELECTRICAL MACHINES (Core Course)

Subject Code	16EPE23	IA Marks	20
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	Exam Marks	80

Credits - 04

Course objectives:

- To provide basic concepts of modelling of dc and ac machines.
- To provide knowledge of theory of transformation of three phase variable to two phase variable.
- To analyze the steady state and dynamic state operation of three-phase induction machines using transformation theory based mathematical modelling.
- To provide modeling concepts of single phase and three phase transformers.
- To analyze the steady state and dynamic state operation of three-phase synchronous machines using transformation theory based mathematical modelling. ■

Module-1	Teaching Hours
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. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

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. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

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. ■	**10**
Revised Bloom's Taxonomy Level: L_2 – Understanding, L_3 – Applying, L_4 – Analysing, L_5 – Evaluating.	

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. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

M.TECH POWER ELECTRONICS (EPE)
16EPE23 MODELLING AND ANALYSIS OF ELECTRICAL MACHINES (Core Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-5	**Teaching Hours**
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. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Design / development of solutions, Conduct investigations of complex Problems, Modern Tool Usage, Ethics,

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text/Reference Books

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

M.TECH POWER ELECTRONICS (EPE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - II

FACTS CONTROLLERS (Core Course)

Course Code	16EPE24	IA Marks	20
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	Exam Marks	80

Credits - 04

Course objectives:

- To discuss the growth of complex electrical power networks and to introduce the lack of controllability of the active- and reactive-power flows in energized networks.
- To describe the conventional controlled systems and introduce the basic operating principles of new FACTS devices
- To describe the various components of a general SVC, its control system, an overview of the voltage-control characteristics of SVC and the principles of design of the SVC voltage regulator.
- To explain the concepts of SVC control in such applications as stability enhancement, damping subsynchronous oscillations, improvement of HVDC link performance and the basic issues relating to the design of SVC controllers in different applications.
- To explain the concepts of series compensation, TCSC controller and its operation, characteristics, modeling and applications.
- To introduce voltage source converter based facts devices. ■

Module-1	Teaching Hours
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). ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	
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. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	
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. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	
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.	**10**

M.TECH POWER ELECTRONICS (EPE)
16EPE24 FACTS CONTROLLERS (Core Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-4 (continued)		**Teaching Hours**
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. ■		
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Lifelong Learning.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text/Reference Books

1	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

M.TECH POWER ELECTRONICS (EPE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - II

CONVERTERS FOR SOLAR AND WIND POWER SYSTEMS (Elective Course)

Course Code	16EPE251	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80

Credits - 03

Course objectives:

- To give an overview of the latest developments in the PV and WT penetrations in the worldwide power systems.
- To discusses the various high-efficiency topologies for PV inverters as well as some generic control structures.
- To describe the grid requirements for PV installations, to give a deep analysis of the basic PLL and to discuss different quadrature signal generator methods,
- To discuss islanding detection methods and to describe the most typical WT grid converter topologies together with generic control structures, the most recent grid requirements for WT grid connection and the grid codes.
- To extrapolate the knowledge of single-phase PLL structure for three-phase systems, new robust synchronization structures to cope with the unbalance grid or frequency adaptation.
- To explain the most used grid converter control structures for WT and to extrapolate the control issue for the case of grid faults.
- To explain designing of grid interface filters, methods actively used to damp the resonance for LCL filters and methods for controlling the grid current. ■

Module-1		Teaching Hours
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

M.TECH POWER ELECTRONICS (EPE) 16EPE251 CONVERTERS FOR SOLAR AND WIND POWER SYSTEMS (Elective Course) (continued) CHOICE BASED CREDIT SYSTEM (CBCS)		
Module-4		**Teaching Hours**
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Design / development of solutions.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text Book

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

M.TECH POWER ELECTRONICS (EPE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - II

UNINTERRUPTIBLE POWER SUPPLY (Elective Course)

Course Code	16EPE252	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80

Credits - 03

Course objectives:

- To explain the classification of UPS, batteries for UPS, parallel operation and performance evaluation and control of UPS systems.
- To describe sources of harmonics, effects of harmonics in UPS, and their mitigation using active filters.
- To describe different topologies of active filters, their applications, configurations, control methods, modelling and analysis, and stability issues.
- To explain the analysis, control, and steady-state operation of unified power quality conditioners.
- To give the concept of reduced parts converters, their operation, modelling, simulation and analysis.
- To explain reduced part active filters and power quality conditioners, modelling, analysis and design of digital control. ■

Module	Teaching Hours
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. ■	**08**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	
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. ■	**08**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	
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. ■	**08**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	
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. ■	**08**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding.	
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. ■	**08**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying.	

M.TECH POWER ELECTRONICS (EPE)
16EPE252 UNINTERRUPTIBLE POWER SUPPLY (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Design / development of solutions, Modern Tool Usage.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text/Reference Books

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

M.TECH POWER ELECTRONICS (EPE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - II

POWER QUALITY PROBLEMS AND MITIGATION (Elective Course)

Course Code	16EPE253	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80

Credits - 03

Course objectives:

- To give an introduction on power quality (PQ), causes and effects of PQ problems, requirement of PQ improvements, and mitigation aspects of PQ problems.
- To give PQ definitions, terminologies, standards, benchmarks, monitoring requirements through numerical problems.
- To explain passive shunt and series compensation using lossless passive LC components, active shunt compensation using DSTATCOM (distribution static compensators), active series compensation using DVR (dynamic voltage restorer), and combined compensation using UPQC (unified power quality compensator) for mitigation of current-based PQ problems.
- To explain classification, modeling and analysis of various nonlinear loads which cause the power quality problems. ■

Module-1		Teaching Hours
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
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). ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

M.TECH POWER ELECTRONICS (EPE) 16EPE253 POWER QUALITY PROBLEMS AND MITIGATION (Elective Course) (continued) CHOICE BASED CREDIT SYSTEM (CBCS)		
Module-5		**Teaching Hours**
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Design / development of solutions, Modern Tool Usage, Engineers and society, Ethics, Individual and Team work, Communication, Lifelong Learning.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text Book

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

M.TECH POWER ELECTRONICS (EPE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - II			
HYBRID ELECTRIC VEHICLES (Elective Course)			
Course Code	16EPE254	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80
Credits - 03			

Course objectives:

- To explain the basics of electric and hybrid electric vehicles, their architecture, technologies and fundamentals.
- To explain plug – in hybrid electric vehicle architecture, design and component sizing and the power electronics devices used in hybrid electric vehicles.
- To discuss various electric drives suitable for hybrid electric vehicles
- To discuss different energy storage technologies used for hybrid electric vehicles and their control.
- To explain modeling and simulation of electric hybrid vehicles by different techniques, sizing of components and design optimization and energy management. ■

Module-1	Teaching Hours
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. ■	**08**
Revised Bloom's Taxonomy Level — L_1 – Remembering, L_2 – Understanding.	
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. ■	**08**
Revised Bloom's Taxonomy Level — L_1 – Remembering, L_2 – Understanding.	
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. ■	**08**
Revised Bloom's Taxonomy Level — L_1 – Remembering, L_2 – Understanding.	
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. ■	**08**
Revised Bloom's Taxonomy Level — L_1 – Remembering, L_2 – Understanding.	

M.TECH POWER ELECTRONICS (EPE) 16EPE254 HYBRID ELECTRIC VEHICLES (Elective Course) (continued) CHOICE BASED CREDIT SYSTEM (CBCS)		
Module-5		**Teaching Hours**
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Modern Tool Usage, Individual and Team work, Communication.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text Book

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

M.TECH POWER ELECTRONICS (EPE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - II			
POWER ELECTRONIS LABORATORY-2			
Course Code	16EPEL26	IA Marks	20
Number of Practical Hours/Week	03	Exam Hours	03
Total Number of Practical Hours	40	Exam Marks	80
Credits - 02			

Course objectives:

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

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.

Revised Bloom's Taxonomy Level	L_1- Remembering, L_2 – Understanding L_3 – Applying, L_4 – Analysing, L_5 – Evaluating.

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Conduct investigations of complex Problems, Modern Tool Usage, Individual and Team work, Communication.

M.TECH POWER ELECTRONICS (EPE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - II			
SEMINAR			
Course Code	16EPE27	IA Marks	100
No. of Lecture Hours/Week	--	Exam Hours	--
Number of contact Hours/week	03	Number of Tutorial Hours/week	--
Total No. of contact Hours	--	Exam Marks	--
Credits - 01			

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, 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 Internal Assessment 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 Chairman. ■

Marks distribution for internal assessment of the course 16EPE27 seminar:
Seminar Report: 30 marks
Presentation skill:50 marks
Question and Answer:20 marks

Graduate Attributes (As per NBA):
Engineering Knowledge, Problem Analysis, Design / development of solutions, Conduct investigations of complex Problems, Modern Tool Usage, Engineers and society, Environment and sustainability, Ethics, Individual and Team work, Communication.

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI

SCHEME OF TEACHING AND EXAMINATION - 2016-17

M.Tech POWER EECRTONICS (EPE)

CHOICE BASED CREDIT SYSTEM (CBCS)

(Total number of credits prescribed for the programme - 85)

III SEMESTER

Sl. No	Course Code	Title	Teaching Hours /Week		Examination				Credits
			Theory	Practical/ Field work/ Assignment	Duration in hours	I.A. Marks	Theory/ Practical Marks	Total Marks	
1	16EPE31	Seminar / Presentation on Internship. (After 8 weeks from the date of commencement)			--	25	--	25	20
2	16EPE32	Report on Internship	--	--	--	25	--	25	
3	16EPE33	Evaluation and Viva-Voce of Internship	--	--	--	--	50	50	
4	16EPE34	Evaluation of Project phase -1	--	--	--	50	--	50	1
TOTAL			--	--	--	**100**	**50**	**150**	**21**

Number of credits completed at the end of III semester: 22+ 22 + 21 = 65

Note:

Internship of 16 weeks shall be carried out during III semester.

Major part of the Project work shall also be carried out during the III semester in consultation with the Guide/s.

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI

SCHEME OF TEACHING AND EXAMINATION - 2016-17

M.Tech POWER EECRTONICS (EPE)

CHOICE BASED CREDIT SYSTEM (CBCS)

(Total number of credits prescribed for the programme - 85)

IV SEMESTER

Sl. No	Course Code	Title	Teaching Hours /Week		Examination				Credits
			Theory	Practical/ Field work/ Assignment	Duration in hours	I.A. Marks	Theory/ Practical Marks	Total Marks	
1	16EPE41	HVDC power Transmission	04	--	03	20	80	100	4
2	16EPE42X	Elective - 3	03	--	03	20	80	100	3
3	16EPE43	Evaluation of Project phase - 2	--	--	--	50	-	50	3
4	16EPE44	Evaluation of Project and Viva-Voce	--	--	--	--	100 + 100	200	10
TOTAL			**07**	**--**	**06**	**90**	**360**	**450**	**20**

Number of credits completed at the end of IV semester: 22+ 22 + 21 + 20 = 85

Elective - 3

Course Code under 16EPE42X	Title
16EPE421	Digital Power Electronics
16EPE422	MPPT in Solar Systems
16EPE423	Multi-Terminal DC Grids
16EPE424	Multilevel Converters for Industrial Applications

Note: 1. Project Phase-1: 6-week duration shall be carried out between 2nd and 3rd Semester vacation. Candidates in consultation with the guide shall carry out literature survey/ visit industries to finalize the topic of Project.

2. Project Phase-2: 16-week duration during 4th semester**.** Evaluation shall be done by the committee comprising of HoD as Chairman, Guide and Senior faculty of the department.

3. **Project Evaluation**: Evaluation shall be taken up at the end of 4th semester. Project work evaluation and Viva-Voce examination shall conducted

4**. Project evaluation:**

a. Internal Examiner shall carry out the evaluation for 100 marks.
b. External Examiner shall carry out the evaluation for 100 marks.
c .The average of marks allotted by the internal and external examiner shall be the final marks of the project evaluation.
d. Viva-Voce examination of Project work shall be conducted jointly by Internal and External examiner for 100 marks.

M.TECH POWER ELECTRONICS (EPE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - IV			
HVDC POWER TRANSMISSION (Core Course)			
Course Code	16EPE41	IA Marks	20
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	Exam Marks	80
Credits - 04			

Course objectives:

- To give an introduction to DC power transmission and describe the basic components of a converter, and describe the methods for compensating the reactive power demanded by the converter and the methods for simulation of HVDC systems
- To describe the types of filters for removing harmonics and the characteristics of the system impedance resulting from AC filter designs and different methods of control of HVDC converter and system.
- To explain the design techniques for the main components of an HVDC system.
- To explain the protection of HVDC system and other converter configurations used for the HVDC transmission and the recent trends for HVDC applications. ■

Module-1		**Teaching Hours**
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
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. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

M.TECH POWER ELECTRONICS (EPE)
16EPE41 HVDC POWER TRANSMISSION (Core Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Lifelong Learning.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text/Reference Books

1	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	2^{nd} Edition, 1998
4	HVDC Transmission	S. Kamakshaiah et al	Mc Graw Hill	2011
5	HVDC and FACTs Controllers; Applications of Static Converters in Power Systems	Vijay K Sood	BSP Books	2013
6	HVDC Power Transmission Systems	K. R. Padiyar	New Age International	2012

M.TECH POWER ELECTRONICS (EPE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - IV			
DIGITAL POWER ELECTRONICS (Elective Course)			
Course Code	16EPE421	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80
Credits - 03			

Course objectives:

- To give introduction to multi quadrant operation and choppers, digital power electronic circuits, power semiconductor devices applied in power electronics and the important factors involved in digital power electronics.
- To explain basic mathematics of digital control systems and mathematical modeling of digitally controlled power electronic devices such as rectifiers, inverters and converters
- To explain open loop and closed loop control of power electronic devices and energy factor application of AC and DC motor drives. ■

Module-1		Teaching Hours
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying.	
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.		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying.	

M.TECH POWER ELECTRONICS (EPE)
16EPE421 DIGITAL POWER ELECTRONICS (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-5	**Teaching Hours**
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. ■	**08**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying.	

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text Book

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

<table>
<tr><td colspan="4">M.TECH POWER ELECTRONICS (EPE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - IV</td></tr>
<tr><td colspan="4">MPPT IN SOLAR SYSTEMS (Elective Course)</td></tr>
<tr><td>Course Code</td><td>16EPE422</td><td>IA Marks</td><td>20</td></tr>
<tr><td>Number of Lecture Hours/Week</td><td>03</td><td>Exam Hours</td><td>03</td></tr>
<tr><td>Total Number of Lecture Hours</td><td>40</td><td>Exam Marks</td><td>80</td></tr>
<tr><td colspan="4">Credits - 03</td></tr>
</table>

Course objectives:

- To explain the PV cell, its characteristics and its models, equivalent circuits and circuit parameter calculations.
- To explain different methods of tracking maximum power point and effect of noise on MPPT and reduction of noise.
- To explain distributed Maximum Power Point Tracking of PV arrays and its analysis.
- To explain the design of high energy efficiency power converters for PV MPPT. ■

<table>
<tr><td colspan="2">Module-1</td><td>Teaching Hours</td></tr>
<tr><td colspan="2">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><td rowspan="2">08</td></tr>
<tr><td>Revised Bloom's Taxonomy Level</td><td>L_1 – Remembering, L_2 – Understanding.</td></tr>
<tr><td colspan="3">Module-2</td></tr>
<tr><td colspan="2">Maximum Power Point Tracking (continued): Improvements of the P&O Algorithm, Evolution of the Perturbative Method, PV MPPT via Output Parameters, MPPT Efficiency.
MPPT Efficiency: Noise Sources and Methods for Reducing their Effects: Low-Frequency Disturbances in Single-Phase Applications, Instability of the Current-Based MPPT Algorithms, Sliding Mode in PV System, Analysis of the MPPT Performances in a Noisy Environment, Numerical Example.■</td><td rowspan="2">08</td></tr>
<tr><td>Revised Bloom's Taxonomy Level</td><td>L_1 – Remembering, L_2 – Understanding.</td></tr>
<tr><td colspan="3">Module-3</td></tr>
<tr><td colspan="2">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><td rowspan="2">08</td></tr>
<tr><td>Revised Bloom's Taxonomy Level</td><td>L_1 – Remembering, L_2 – Understanding.</td></tr>
<tr><td colspan="3">Module-4</td></tr>
<tr><td colspan="2">Distributed Maximum Power Point Tracking of Photovoltaic Arrays (continued): AC Analysis of a PV Array with DMPPT. ■</td><td rowspan="2">08</td></tr>
<tr><td>Revised Bloom's Taxonomy Level</td><td>L_1 – Remembering, L_2 – Understanding.</td></tr>
<tr><td>Module-5</td><td></td><td></td></tr>
<tr><td colspan="2">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><td rowspan="2">08</td></tr>
<tr><td>Revised Bloom's Taxonomy Level</td><td>L_1 - Remembering, L_2 - Understanding, L_3 - Applying</td></tr>
<tr><td colspan="3"></td></tr>
</table>

M.TECH POWER ELECTRONICS (EPE)
16EPE422 MPPT IN SOLAR SYSTEMS (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Design / development of solutions, Lifelong Learning.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text Book

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

M.TECH POWER ELECTRONICS (EPE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - IV

MULTI-TERMINAL DC GRIDS (Elective Course)

Course Code	16EPE423	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80

Credits - 03

Course objectives:

- To provide the fundamentals of MTDC grids, their network architectures, components and control modes and basics of voltage sourced converters.
- To explain modeling, simulation and analysis of AC- MTDC grids
- To explain the concept of power sharing in MTDC grid, load flow solution and post contingency operation
- To explain protection issues of MTDC grids, including the DC circuit breakers and fault blocking VSC systems and protection strategies. ■

Module-1		**Teaching Hours**
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.■		**08**
Revised Bloom's Taxonomy Level	L_1 - Remembering, L_2 - Understanding, L_3 - Applying.	
Module-2		
Voltage-Sourced Converter (continued): Control, Simulation. **Modelling, Analysis, and Simulation of AC–MTDC Grids:** Introduction, MTDC Grid Model. ■		**08**
Revised Bloom's Taxonomy Level	L_1 - Remembering, L_2 - Understanding, L_3 - Applying, L_4 – Analysing.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 - Remembering, L_2 - Understanding, L_3 - Applying, L_4 – Analysing.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 - Remembering, L_2 - Understanding, L_3 - Applying, L_4 – Analysing.	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

M.TECH POWER ELECTRONICS (EPE)
16EPE423 MULTI-TERMINAL DC GRIDS (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Modern Tool Usage, Lifelong Learning.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text Book

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

M.TECH POWER ELECTRONICS (EPE) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - IV			
MULTILEVEL CONVERTERS FOR INDUSTRIAL APPLICATIONS (Elective Course)			
Course Code	16EPE424	IA Marks	20
Number of Lecture Hours/Week	03	Exam Hours	03
Total Number of Lecture Hours	40	Exam Marks	80
Credits - 03			

Course objectives:

- To provide an overview of medium-voltage power converters and their applications.
- To describe the generalized multilevel converter topology and to derive the classic converters with a common DC bus and to analyze the common characteristics of the symmetric topologies.
- Explain the analysis of the operation of the diode-clamped multilevel converter, and a multilevel space vector modulation and to characterize the balancing boundary of the passive front-end converter
- To describe the operation and analysis of the flying capacitor multilevel converter.
- To explain asymmetric topology with hybrid modulation and a common DC source called a cascade asymmetric multilevel converter (CAMC) with five voltage levels and its advantages.
- To analysee the behaviour of the CAMC as a distribution static compensator (DSTATCOM) and shunt active power filter in improving the power quality in medium-voltage distribution systems as custom power devices.
- To analyse the behaviour of the diode-clamped topology configured as a back-to-back converter for several working conditions. ■

Module-1		**Teaching Hours**
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 - Remembering, L_2 - Understanding, L_3 - Applying, L_4 - Analyzing, L_5 - Evaluating, L_6 - Creating	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 - Remembering, L_2 - Understanding, L_3 - Applying, L_4 - Analyzing, L_5 - Evaluating, L_6 - Creating	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 - Remembering, L_2 - Understanding, L_3 - Applying, L_4 - Analyzing, L_5 - Evaluating, L_6 - Creating	
Module-4		
Case Study 1: DSTATCOM Built with a Cascade Asymmetric Multilevel Converter: Introduction, Compensation Principles, CAMC Model, Reactive Power and Harmonics Compensation. ■		**08**
Revised Bloom's Taxonomy Level	L_1 - Remembering, L_2 - Understanding, L_3 - Applying, L_4 - Analyzing, L_5 - Evaluating, L_6 - Creating	
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 - Remembering, L_2 - Understanding, L_3 - Applying, L_4 - Analyzing, L_5 - Evaluating, L_6 - Creating	

M.TECH POWER ELECTRONICS (EPE)
16EPE424 MULTILEVEL CONVERTERS FOR INDUSTRIAL APPLICATIONS (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

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. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 16 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text Book

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

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