VISVESVARAYA TECHNOLOGICAL UNIVERSITY
BELAGAVI

Scheme of Teaching and Examination and Syllabus
M.Tech POWER SYSTEM ENGINEERING (EPS)

Eligibility: Bachelor’s degree in Engineering or Technology in
(a)Electrical and Electronics (b) AMIE in appropriate branch (c) GATE: 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 SYSTEM ENGINEERING (EPS)
CHOICE BASED CREDIT SYSTEM (CBCS)
(Total number of credits prescribed for the programme - 85)

I SEMESTER

Sl. No	Subject 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	16EPS12	Modelling and Analysis of Electrical Machines	04	--	03	20	80	100	4
3	16EPS13	Power system Dynamics (Stability and Control)	04	--	03	20	80	100	4
4	16EPS14	Computer Relaying for Power Systems	04	--	03	20	80	100	4
5	16EPS15X	Elective -1	03	--	03	20	80	100	3
6	16EPSL16	Power System Laboratory - I	-	3	03	20	80	100	2
7	16EPS17	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

Courses under Code 16EPS15X	Title
16EPS151	EHV AC Transmission
16EPS152	Power System Harmonics
16EPS153	Linear and Nonlinear Optimization
16EPS154	Power System Voltage Stability

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

II SEMESTER

Sl. No	Subject Code	Title	Teaching Hours /Week		Examination				Credits
			Theory	Practical/ Field work/ Assignment	Duration in hours	I.A. Marks	Theory/ Practical Marks	Total Marks	
1	16EPS21	Power Electronic Converters	04	--	03	20	80	100	4
2	16EPS22	Insulators for Power System	04	--	03	20	80	100	4
3	16EPS23	Switching in Power Systems	04	--	03	20	80	100	4
4	16EPS24	FACTS Controllers	04	--	03	20	80	100	4
5	16EPS25X	Elective - 2	03	--	03	20	80	100	3
6	16EPSL26	Power System Laboratory - II	-	3	03	20	80	100	2
7	16EPS27	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

Courses under Code 16EPS25X	Title
16EPS251	Restructured Power Systems
16EPS252	Smart Grid
16EPS253	Power Quality Problems and Mitigation
16EPS254	Substation Automation Systems

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.

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III SEMESTER

Sl. No	Subject Code	Title	Teaching Hours /Week		Examination				Credits
			Theory	Practical/ Field work/ Assignment	Duration in hours	I.A. Marks	Theory/ Practical Marks	Total Marks	
1	16EPS31	Seminar / Presentation on Internship. (After 8 weeks from the date of commencement)	--	--	--	25	--	25	20
2	16EPS32	Report on Internship	--	--	--	25	--	25	
3	16EPS33	Evaluation and Viva-Voce of Internship	--	--	--	--	50	50	
4	16EPS34	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.

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SCHEME OF TEACHING AND EXAMINATION - 2016-17
M.Tech POWER SYSTEM ENGINEERING (EPS)
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(Total number of credits prescribed for the programme - 85)

IV SEMESTER

Sl. No	Subject Code	Title	Teaching Hours /Week		Examination				Credits
			Theory	Practical/ Field work/ Assignment	Duration in hours	I.A. Marks	Theory/ Practical Marks	Total Marks	
1	16EPS41	HVDC Power Transmission	04	--	03	20	80	100	4
2	16EPS42X	Elective - 3	03	--	03	20	80	100	3
3	16EPS43	Evaluation of Project phase - 2	--	--	--	50	-	50	3
4	16EPS44	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

Courses under Code 16EPS42X	Title
16EPS421	Power System Reliability
16EPS422	Wide Area Measurements and their Applications
16EPS423	Multi-Terminal DC Grids
16EPS424	Integration of Renewable Energy

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.

<table>
<tr><td colspan="4">M.TECH POWER SYSTEM ENGINEERING (EPS)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - I</td></tr>
<tr><td colspan="4">APPLIED MATHAMATICS (Core Course)</td></tr>
<tr><td>Course Code</td><td>16EEE11</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:

- 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. ■

<table>
<tr><td colspan="2">Module-1</td><td>Teaching Hours</td></tr>
<tr><td colspan="2">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.■</td><td rowspan="2">10</td></tr>
<tr><td>Revised Bloom's Taxonomy Level</td><td>L_2 – Understanding, L_3 – Applying</td></tr>
<tr><td colspan="3">Module-2</td></tr>
<tr><td colspan="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. ■</td><td rowspan="2">10</td></tr>
<tr><td>Revised Bloom's Taxonomy Level</td><td>L_3 – Applying</td></tr>
<tr><td colspan="3">Module-3</td></tr>
<tr><td colspan="2">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.■</td><td rowspan="2">10</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">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. ■</td><td rowspan="2">10</td></tr>
<tr><td>Revised Bloom's Taxonomy Level</td><td>L_3 – Applying</td></tr>
<tr><td colspan="3">Module-5</td></tr>
<tr><td colspan="2">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. ■</td><td rowspan="2">10</td></tr>
<tr><td>Revised Bloom's Taxonomy Level</td><td>L_3 – Applying, L_4 – Analysing.</td></tr>
<tr><td colspan="3"></td></tr>
</table>

M.TECH POWER SYSTEM ENGINEERING (EPS)
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*			

M.TECH POWER SYSTEM ENGINEERING (EPS)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - I

MODELLING AND ANALYSIS OF ELECTRICAL MACHINES (Core Course)

Subject Code	16EPS12	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 SYSTEM ENGINEERING (EPS)
16EPS12 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 SYSTEM ENGINEERING (EPS)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - I

POWER SYSTEM DYNAMICS (STABILITY AND CONTROL) (Core Course)

Subject Code	16EPS13	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 on dynamic modeling of a synchronous machine excitation and prime mover controllers.
- To describe the modeling of transmission lines, SVC and loads.
- To explain the dynamics of single machine connected to infinite bus.
- To describe the analysis of single and multi-machine systems and evaluation of transient stability. ■

Module-1	Teaching Hours
Basic Concepts of Power System: Introduction, Power System Stability, States of Operation and System Security, System Dynamic Problems. **Analysis of system stability:** System Model, Mathematical Preliminaries, Analysis of Steady State Stability and Transient Stability, Excitation Control. **Modelling of Synchronous Machine:** Introduction, Synchronous Machine, Park's Transformation, Analysis of Steady State Performance, Per Unit Quantities. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
Module-2	
Modelling of Synchronous Machine (continued): Equivalent Circuits of Synchronous Machine, Determination of Parameters of Equivalent Circuits, Measurements for obtaining Data, Saturation Models, Transient Analysis of a Synchronous Machine, Power System Dynamics - Stability and Control. **Excitation and Prime Mover Controllers:** Excitation System, Excitation System Modelling, Excitation Systems- Standard Block Diagram, System Representation by State Equations, Prime-Mover Control System. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
Module-3	
Transmission Lines, SVC and Loads: Transmission Lines, D-Q Transformation using alpha and beta Variables), Static Var compensators, Loads. **Dynamics of a Synchronous Generator Connected to Infinite Bus:** System Model, Synchronous Machine Model, Application of Model 1.1, Calculation of Initial Conditions, System Simulation, Consideration of other Machine Models. Inclusion of SVC Model. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing. L_5 – Evaluating, L_6 – Creating.	
Module-4	
Analysis of Single Machine System: Small Signal Analysis with Block Diagram Representation, Characteristic Equation and Application of Routh-Hurwitz Criterion, Synchronizing and Damping Torques Analysis, Small Signal Model: State Equations, Nonlinear Oscillations - Hopf Bifurcation. **Application of Power System Stabilizers:** Introduction, Basic concepts in applying PSS, Control Signals, Structure and tuning of PSS, Field implementation and operating experience, Examples of PSS Design and Application. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

M.TECH POWER SYSTEM ENGINEERING (EPS) 16EPS13 POWER SYSTEM DYNAMICS (STABILITY AND CONTROL) (Core Course) (continued) CHOICE BASED CREDIT SYSTEM (CBCS)		
Module-5		**Teaching Hours**
Analysis of Multimachine System: A Simplified System Model, Detailed Models: Case I and Case II, Inclusion of Load and SVC Dynamics, Modal Analysis of Large Power Systems, Case Studies. **Simulation for Transient Stability Evaluation:** Mathematical Formulation, Solution Methods, Formulation of System Equations, Solution of System Equations, Simultaneous Solution, Case Studies, Dynamic Equivalents and Model Reduction. ■		**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 states of operation, system security and dynamic problems
- Use model of power system to assess system stability
- Model synchronous machine transmission line and loads.
- Model excitation and prime movers systems and static var systems.
- Use model to study the dynamics of a synchronous generator connected to infinite bus.
- Use models to analyze the single machine system connected to infinite bus.
- Discuss the use of power system stabilizers
- Use models of the multi machine system for the transient stability analysis. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Design / development of solutions, Conduct investigations of complex Problems, 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	Power System Dynamics Stability and Control	K.R. Padiyar	B.S. Publications	2nd Edition,2008
2	Power system control and stability	P.M. Anderson et al	B.S. Publications	2nd Edition,2003
3	Power System Dynamics and Stability	Peter W. Sauer et al	PHI	1st Edition, 1998

M.TECH POWER SYSTEM ENGINEERING (EPS)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - I

COMPUTER RELAYING FOR POWER SYSTEMS (Core Course)

Subject Code	16EPS14	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 explain the importance of computer relaying in power systems and different relaying practices.
- Provide mathematical basis for protective relaying algorithm and digital filters.
- To explain protection algorithm for transformers transmission lines.
- To explain relying applications of travelling waves in single and three phase lines. ■

Module-1	Teaching Hours
Introduction to computer relaying: Development of computer relaying, historical background , expected benefits of computer relaying, computer relay architecture, analog to digital converters, anti-aliasing filters, substation computer hierarchy. **Relaying practices:** Introduction to protection systems, functions of a protection system, protection of transmission lines, transformer, reactor and generator protection, bus protection, performance of current and voltage transformers. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying.	
Module-2	
Mathematical basis for protective relaying algorithms: Introduction, Fourier series, other orthogonal expansions, Fourier transforms, use of Fourier transforms, discrete Fourier transform, introduction to probability and random process, random processes, Kalman filtering. **Digital filters:** Introduction, discrete time systems, discrete time systems, Z Transforms, digital filters, windows and windowing, linear phase, Approximation – filter synthesis, wavelets, elements of artificial intelligence. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying.	
Module-3	
Transmission line relaying: Introduction, sources of error, relaying as parameter estimation, beyond parameter estimation, symmetrical component distance relay, newer analytic techniques, protection of series compensated . **Protection of transformers, machines and buses:** Introduction, power transformer algorithms, generator protection, motor protection, digital bus protection. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying.	
Module-4	
Hardware organization in integrated systems: The nature of hardware issues, computers for relaying, the substation environment, industry environmental standards, countermeasures against EMI, supplementary equipment, redundancy and backup, servicing, training and maintenance. **System relaying and control**: Introduction, measurement of frequency and phase, sampling clock synchronization, application of phasor measurements to state estimation, phasor measurements in dynamic state estimation, monitoring, control applications. ■	**10**
Revised Bloom's Taxonomy Level: L_1 – Remembering, L_2 – Understanding, L_3 – Applying.	

M.TECH POWER SYSTEM ENGINEERING (EPS)
16EPS14 COMPUTER RELAYING FOR POWER SYSTEMS (Core Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-5		**Teaching Hours**
Relaying applications of traveling waves: Introduction, traveling waves on single-phase lines, traveling waves on three-phase lines, directional wave relay, traveling wave distance relay, differential relaying with phasors, traveling wave differential relays, fault location, other recent developments. **Wide area measurement applications**: Adaptive relaying, examples of adaptive relaying, wide area measurement systems (WAMS), WAMS architecture, WAMS based protection concepts. ■		**10**
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 advantages of computer relaying, its architecture and relaying practices used in power system.
- Provide mathematical basis for protective relaying algorithms.
- Explain digital filters used in computer relaying.
- Discuss transmission line relaying.
- Explain protection transformers, machines and buses.
- Explain hardware organization for computer relaying, system relaying.
- Explain relaying applications for travelling waves.
- Explain adaptive relaying and WAMS based protection.■

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 Book

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

M.TECH POWER SYSTEM ENGINEERING (EPS)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - I

EHV AC TRANSMISSION (Elective Course)

Subject Code	16EPS151	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 introduce recent trends in electrical power transmission and to evaluate line parameters.
- To explain the voltage gradients on conductor, corona and its effects.
- To explain the theory of travelling and standing waves on the power transmission lines.
- To explain protection of transmission lines from lightning and switching over voltages.
- To explain power frequency voltage control and design of EHV lines. ■

Module-1	Teaching Hours
Transmission Line Trends and Preliminaries: Role of EHV AC Transmission, Standard Transmission Voltages, Average Values of Line Parameters, Power-Handling Capacity and Line Loss, Examples of Giant Power Pools and Number of Lines, Costs of Transmission Lines and Equipment, Mechanical Considerations in Line Performance. **Calculation of Line and Ground Parameters:** Resistance of Conductors, Temperature Rise of Conductors and Current-Carrying Capacity, Properties of Bundled Conductors, Inductance of EHV Line Configurations, Line Capacitance Calculation, Sequence Inductances and Capacitances, Line Parameters for Modes of Propagation, Resistance and Inductance of Ground Return. ■	**08**
Revised Bloom's Taxonomy Level — L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing, L_5 – Evaluating.	
Module-2	
Voltage Gradients of Conductors: Electrostatics, Field of Sphere Gap, Field of Line Charges and Their Properties, Charge-Potential Relations for Multi-Conductor lines, Surface Voltage Gradient on Conductors, Examples of Conductors and Maximum Gradients on Actual Lines, Gradient Factors and Their Use, Distribution of Voltage Gradient on Sub-conductors of Bundle, Design of Cylindrical Cages for Corona Experiments, Voltage Gradients on Conductors in the Presence of Ground Wires on Towers. ■	**08**
Revised Bloom's Taxonomy Level — L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing, L_5 – Evaluating.	
Module-3	
Corona: I^2R Loss and Corona Loss, Corona-Loss formulae, Attenuation of Travelling Waves due to Corona Loss, Audible Noise: Generation and Characteristics, Limits for Audible Noise. Generation of Corona Pulses and their Properties, Properties of Pulse Trains and Filter Response, Limits for Radio Interference Fields. **Theory of Travelling Waves and Standing Waves**: Travelling Waves and Standing Waves at Power Frequency, Differential Equations and Solutions for General Case, Standing Waves and Natural Frequencies, Open-Ended Line: Double-Exponential Response, Open-Ended Line: Response to Sinusoidal Excitation, Line Energization with Trapped-Charge Voltage, Corona Loss and Effective Shunt Conductance, The Method of Fourier Transforms, Reflection and Refraction of Travelling Waves, Transient Response of Systems with Series and Shunt Lumped Parameters and Distributed Lines, Principles of Travelling-Wave Protection of EHV Lines.■	**08**
Revised Bloom's Taxonomy Level — L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing, L_5 – Evaluating.	

M.TECH POWER SYSTEM ENGINEERING (EPS)
16EPS151 EHV AC TRANSMISSION (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-4		**Teaching Hours**
Lightning and Lightning Protection: Lightning Strokes to Lines, Lightning-Stroke Mechanism, General Principles of the Lightning-Protection Problem, Tower-Footing Resistance, Insulator Flashover and Withstand Voltage, Probability of Occurrence of Lightning-Stroke Currents, Lightning Arresters and Protective Characteristics, Dynamic Voltage Rise and Arrester Rating, Operating Characteristics of Lightning Arresters, Insulation Coordination Based on Lightning. **Over voltages in EHV Systems Caused by Switching Operations:** Origin of Overvoltages and Their Types, Short-Circuit Current and the Circuit Breaker, Recovery Voltage and the Circuit Breaker, Overvoltages Caused by Interruption of Low Inductive Current, Interruption of Capacitive Currents, Ferro-Resonance Overvoltages, Calculation of Switching Surges—Single Phase Equivalents, Distributed-Parameter Line Energized by Source, Generalized Equations for Single-Phase Representation, Generalized Equations for Three-Phase Systems, Inverse Fourier Transform for the General Case, Reduction of Switching Surges on EHV Systems, Experimental and Calculated Results of Switching-Surge Studies. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing, L_5 – Evaluating.	
Module-5		
Power-Frequency Voltage Control and Over voltages: Problems at Power Frequency, Generalized Constants, No-Load Voltage Conditions and Charging Current, The Power Circle Diagram and Its Use, Voltage Control Using Synchronous Condensers, Cascade Connection of Components—Shunt and Series Compensation, Sub-Synchronous Resonance in Series-Capacitor Compensated Lines, Static Reactive Compensating Systems (Static VAR), High Phase Order Transmission. **Design of EHV Lines Based upon Steady-State Limits and Transient Overvoltages**: Introduction, Design Factors Under Steady State, Design Examples: Steady-State Limits, Design Examples I to IV, Line Insulation Design Based Upon Transient Overvoltages. ■		**08**
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:

- Explain power transmission at extra high voltages.
- Calculate Line and Ground Parameters of transmission lines.
- Estimate the voltage gradients on conductor.
- Explain corona phenomenon on transmission line.
- Explain the propagation of travelling waves and formation of standing waves on transmission lines.
- Explain protection methods for lightening and switching surges on transmission lines.
- Explain power frequency voltage control over voltage on transmission line.
- Design of EHV Lines Based upon Steady-State Limits and Transient Overvoltages. ■

Graduate Attributes (As per NBA):

Engineering Knowledge Problem Analysis, Design / development of solutions, Environment and sustainability, Ethics, Individual and Team work.

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	Extra High Voltage AC Transmission Engineering	Rakosh Das Begamudre	New Age International Publishers.	4^{th} Edition,2011

M.TECH POWER SYSTEM ENGINEERING (EPS)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - I

POWER SYSTEM HARMONICS (Elective Course)

Subject Code	16EPS152	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 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. ■

Module-1		Teaching Hours
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
Module-2		
Effects of Harmonic Distortion on Power System: Introduction, thermal losses in a harmonic environment, harmonic effects on power system equipment, capacitor banks, transformers, rotating machines, protection, communication and electronic equipment. **Mitigation of Power system Harmonics:** Introduction, harmonic filters, power converters, transformers, rotating machines, capacitor banks, harmonic filter design, active filters. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
Module-3		
Limits of Harmonic Distortion: Introduction, voltage harmonic distortion limits, current harmonic distortion limits. **Harmonic studies – Modelling of System Components:** Introduction, impedance in the presence of harmonics, skin effect, modelling of the high voltage grid, generator modelling, modelling of shunt capacitor banks, series capacitor banks, load models, induction motor modelling. **Transformer Modelling:** Introduction, modelling of two winding transformers, phase sequence admittance matrices, transmission of voltage and current across two winding transformers, transmission matrices and phase admittance matrix, modelling of three and four winding transformers. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

M.TECH POWER SYSTEM ENGINEERING (EPS) 16EPS152 POWER SYSTEM HARMONICS (Elective Course) (continued) CHOICE BASED CREDIT SYSTEM (CBCS)		
Module-4		**Teaching Hours**
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. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
Module-5		
Power System Harmonic Studies: Introduction, harmonic analysis using a computer program, harmonic analysis using spread sheet, harmonic distortion limits, harmonic filter rating, and practical considerations. Harmonic study of simple system, 300 -22 kV power system and low voltage system. ■		**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 fundamental of harmonics.
- Discuss the sources of harmonics in the power system.
- Explain the effects of harmonic distortion on power system.
- Explain the mitigation of harmonics in power system and the limits of harmonic distortion.
- Model generator and transformers for harmonic studies.
- Model transmission system; transmission lines and cables for 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 SYSTEM ENGINEERING (EPS) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - I			
LINEAR AND NONLINEAR OPTIMIZATION (Elective Course)			
Subject Code	16EPS153	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:

- Provide introduction to optimization.
- Explanation to classification of optimization problems.
- Explanation for linear programming and solution of LPP problem.
- Explanation for nonlinear programming and solution of nonlinear programming problem by one dimensional minimization method. ■

Module-1		**Teaching Hours**
Optimization: Introduction, historical development, engineering applications of optimization, statement of an optimization problem, design vector, design constraints, constraint surface, objective function, objective function surfaces, classification of optimization problems based on existence of constraints, nature of the design variables, physical structure of the problem, nature of the equations involved, nonlinear and linear programming problem(NLP and LPP), permissible values of the design variables, deterministic nature of the functions, number of objective functions, optimization techniques. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
Module-2		
Classification of Optimization Problems: Introduction, single variable optimization, multivariable optimization with no constraints, semi-definite case, saddle point, multivariable optimization with equality constraints, solution by direct substitution, by the method of constrained variation and by the method of Lagrange multipliers, multivariable optimization with inequality constraints, Kuhn-Tucker conditions, constraint qualification, Convex programming problem. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
Module-3		
Linear Programming-I: Introduction, applications of linear programming, standard form of a LPP, geometry of LPP, definitions and theorems, solution of a system of linear simultaneous equations, pivotal reduction of a general system of equations, motivation of the simplex method, simplex algorithm, identifying an optimal point, improving a non-optimal basic feasible solution, two phases of the simplex method. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
Module-4		
Linear Programming-II: Revised simplex method, duality in linear programming; symmetric and primal-dual relations, primal-dual relations when the primal is in standard form, duality theorems, dual simplex method, decomposition principle, sensitivity or post- optimality analysis, changes in right-hand-side constants b_i, changes in the cost coefficients C_j, addition of new variables, changes in the constraint coefficients a_{ij}, addition of constraints. Transportation problem, Karmarkar's method, statement of the problem, conversion of an LPP into required form, algorithm, quadratic programming. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

M.TECH POWER SYSTEM ENGINEERING (EPS)
16EPS153 LINEAR AND NONLINEAR OPTIMIZATION (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-5		**Teaching Hours**
Non-Linear Programming - One Dimensional Minimization Methods: Introduction, Unimodal function, Unrestricted search with fixed step size and accelerated step size, exhaustive search, dichotomous search, interval halving method, Fibonacci method, golden section method, comparison of elimination methods, interpolation methods, quadratic and cubic, direct root methods, Newton, Quasi-Newton and Secant methods, practical considerations. ■		**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:

- Understand engineering applications of optimization
- State the optimization problem, constraints, and objective function.
- Classify optimization problem.
- Solve an optimization problem by direct substitution, by the method of constrained variation and by the method of Lagrange multipliers.
- Use Kuhn-Tucker conditions to solve multivariable optimization problem with inequality constraints.
- Use simplex method for the solving optimization problem represented by linear set of equations.
- Solve linear transportation problem.
- Explain Non-Linear Programming - One Dimensional Minimization Methods of solving optimization problems. ■

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

M.TECH POWER SYSTEM ENGINEERING (EPS) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - I			
POWER SYSTEM VOLTAGE STABILITY (Elective Course)			
Subject Code	16EPS154	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:

- Explain the importance of reactive power transmission, voltage stability in power system and reactive power compensation and control.
- To explain static and dynamic characteristics of loads and generation characteristics.
- To explain voltage stability improvement of large power systems by different methods.
- To explain voltage stability of systems with HVDC links and setting different operating guidelines for generation and transmission systems. ■

Module-1		**Teaching Hours**
Electric Power Systems: Introduction to Power System Analysis and Operation, Active and Reactive Power Transmission, Difficulties with Reactive Power Transmission, Short Circuit Capacity, Short Circuit Ratio, and Voltage, Regulation. **Voltage Stability:** Voltage Stability, Voltage Collapse, and Voltage Security, Time Frames for Voltage Instability, Mechanisms, Relation of Voltage Stability to Rotor Angle Stability, Voltage Instability in Mature Power Systems, P-V and V – Q Curves, Graphical Explanation of Longer-Term Voltage Stability. **Reactive Power Compensation and Control:** Transmission System Characteristics, Series Capacitors, Shunt Capacitor Banks and Shunt Reactors, Static Var Systems, Comparisons between Series and Shunt Compensation, Synchronous Condensers, Transmission Network LTC Transformers. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
Module-2		
Power System Loads: Overview of Subtransmission and Distribution Networks, Static and Dynamic Characteristics of Load Components, Reactive Compensation of Loads, LTC Transformers and Distribution Voltage Regulators. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
Module-3		
Generation Characteristics: Generator Reactive Power Capability, Generator Control and Protection, System Response to Power Impacts, Power Plant Response, Automatic Generation Control (AGC). ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
Module-4		
Voltage Stability of a Large System: System Description, Load Modelling and Testing, Power Flow Analysis, 7.4 Dynamic Performance Including Undervoltage Load Shedding, Automatic Control of Mechanically Switched Capacitors. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

M.TECH POWER SYSTEM ENGINEERING (EPS)
16EPS154 POWER SYSTEM VOLTAGE STABILITY (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-5	**Teaching Hours**
Voltage Stability with HVDC Links: Basic Equations for HVDC, HVDC Operation, Voltage Collapse, Voltage Stability Concepts Based on Short Circuit Ratio, Power System Dynamic Performance, **Power System Planning and Operating Guidelines:** Solutions: Generation System, Solutions: Transmission System, Distribution and Load Systems, Power System Operation, Voltage Stability Challenge. ■	**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 in detail the voltage stability problem.
- Explain reactive power compensation and control to minimize the voltage stability problem.
- Explain the dynamic characteristics of load components and generators in the systems.
- Suggest suitable method for voltage stability improvement of large power system.
- Provide a solution for the voltage stability problem of system with HVDC links.
- Explain operating guidelines for transmission and generation system. ■

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

M.TECH POWER SYSTEM ENGINEERING (EPS) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - I			
POWER SYSTEMS LABORATORY-I			
Subject Code	16EPSL16	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:

- Conduct of experiment for operator request power flow analysis, contingency analysis and ranking for a interconnected power system.
- Conduct of experiment for ATC computation, open access feasibility study, reactive power optimization and loss minimization studies.
- Conduct of experiments for economic dispatch problem, observability analysis, state estimation and bad data detection.
- Conduction of experiments for relay coordination and harmonic analysis. ■

Sl. NO	Experiments
1	Operator request load flow using voltage and frequency dependent load modelling and generator droop characteristic.
2	Contingency analysis and Ranking for a given inter connected power system having minimum ten buses and ten series elements.
3	Obtaining of PV & PQ curve for a given power system with load buses and Voltage instability analysis.
4	ATC computation and open access feasibility studies for the given power system network.
5	Reactive power optimization and loss minimization studies for a given power system.
6	Economic dispatch problem taking into account the network loading constraints and computation of bus incremental cost.
7	Observability analysis, state estimation and bad data detection for a given power system using measurement data.
8	Sequence impedance diagram development and distribution of earth fault current computation in a practical power system having auto transformers with tertiary delta winding, star-delta and delta-star configurations.
9	Over current relay co-ordination with and without instantaneous setting for a given network with NI relay characteristic curves.
10	Harmonic analysis and voltage and current harmonic distortion computation for a given power system. Tuned filter design to eliminate the harmonic currents.

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:

- Apply the knowledge of electrical engineering in conducting different experiment in the laboratory.
- Use suitable simulation software package for the conduction of experiments and analyze the results. ■

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 SYSTEM ENGINEERING (EPS) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - I			
SEMINAR			
Course Code	16EPS17	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 16EPS17 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 SYSTEM ENGINEERING (EPS)
CHOICE BASED CREDIT SYSTEM (CBCS)
(Total number of credits prescribed for the programme - 85)

II SEMESTER

Sl. No	Subject Code	Title	Teaching Hours /Week		Examination				Credits
			Theory	Practical/ Field work/ Assignment	Duration in hours	I.A. Marks	Theory/ Practical Marks	Total Marks	
1	16EPS21	Power Electronic Converters	04	--	03	20	80	100	4
2	16EPS22	Insulators for Power System	04	--	03	20	80	100	4
3	16EPS23	Switching in Power Systems	04	--	03	20	80	100	4
4	16EPS24	FACTS Controllers	04	--	03	20	80	100	4
5	16EPS25X	Elective - 2	03	--	03	20	80	100	3
6	16EPSL26	Power System Laboratory - II	-	3	03	20	80	100	2
7	16EPS 27	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

Courses under Code 16EPS25X	Title
16EPS251	Restructured Power Systems
16EPS252	Smart Grid
16EPS253	Power Quality Problems and Mitigation
16EPS254	Substation Automation Systems

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 SYSTEM ENGINEERING (EPS)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - II

POWER ELECTRONIC CONVERTERS (Core Course)

Course Code	16EPS21	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 SYSTEM ENGINEERING (EPS)
16EPS21 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:

- Explain the basic topology and analysis of PWM DC/ DC in both Continuous (CCM) and Discontinuous Current Mode (DCM).
- Discuss on loss mechanisms in the PWM DC/ DC converters.
- Describes circuits used to control power electronic systems, and their application.
- Explain analysis and control techniques of single-phase and three phase bridge DC/AC Converters.
- Explain the operation, analysis and control techniques of uncontrolled, phase controlled and high power factor PWM AC/DC Converters.
- Describes single-phase and three-phase AC/AC voltage converters, direct and indirect frequency converters and matrix converters and their applications.
- Describes different topologies of Resonant Converters and some control circuits used in resonant converters.
- Explain basic topologies of DC/DC and DC/AC multilevel converters and control techniques used. ■

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 SYSTEM ENGINEERING (EPS) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - II			
INSULATORS FOR POWER SYSTEM (Core Course)			
Course Code	16EPS22	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 define insulator and its terminology and to explain the construction, classification and stresses on insulators.
- To explain design, manufacturing and testing standards of different types of insulators.
- To explain selection of insulators and physics of contamination and pollution flashover.
- To explain terminology of ice, its electrical characteristics, flashover process and icing test methods.
- To explain different tests on insulators and to derive conclusion from the test results. ■

Module-1		**Teaching Hours**
Insulators: Definition, Insulators for Transmission System, Elements of an Insulator. Terminology for Insulators: Classification of Insulators, Insulator Construction, Electrical Stresses on Insulators, Environmental Stresses on Insulators, Mechanical Stresses. ■ (Refer to chapter 01 of JST Looms and chapter 02 of Masoud Farzaneh)		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
Module-2		
Design and Manufacturing of Insulators: Porcelain insulators, Glass Insulators, Nonceramic Insulators. **Testing Standards for Insulators:** Need for Standards, Standards Producing Organizations, Insulator Standards, Classification of Porcelain /Glass Insulator Tests, Brief Description and philosophy of various Tests for /Cap and Pin Porcelain/Glass Insulators, Summary of Standards for Porcelain/Glass Insulators, Standards for Nonceramic (Composite) Insulators, Classification of Tests, Philosophy and Brief Description, Summary of Standards for Non-ceramic Insulators. ■ (Refer to chapters 02 and 03 of Ravi S Gorur)		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
Module-3		
Selection of Insulators: Introduction, Cost and Weight, National Electricity Safety Code (NESC), Basic Lightning Impulse Insulation Level (BIL), Contaminating Performance, Experience with Silicone Rubber Insulators in Salt Areas of Florida, Compaction, Grading Rings for Nonceramic Insulators, Maintenance Inspections. **Physics of contamination:** Electrically significant deposits, Contaminating processes, Purging processes, Equilibrium deposit, Assessment of required insulation: Severity measurement. **Physics of Pollution flashover:** Flash paradox, Stages of the flashover process, Models and empirical theories of complete flashover. ■ (Refer to chapters 04 of Ravi S Gorur, chapters 10 and 11 of JST Looms)		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
Module-4		
Icing Flashovers: Terminology for Ice, Ice Morphology, Electrical Characteristics of Ice, Ice Flashover Experience, Ice Flashover Processes, Icing Test Methods, Ice Flashover Test Results. ■ (Refer to chapter 07 of Masoud Farzaneh)		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

M.TECH POWER SYSTEM ENGINEERING (EPS)
16EPS22 INSULATORS FOR POWER SYSTEM (Core Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-5	**Teaching Hours**
Testing of Insulators: Classes of test, Natural pollution testing: Background, Artificial pollution testing, Comparison of artificial-pollution tests, Source impedance: Effect on test results, Principles of mechanical testing. **Conclusions from pollution test on insulators:** Scope of chapter, Deterioration: test results, validity of testing of insulators. **Insulator of the future:** Indicators from known facts, Extrapolation from current practices.■ (Refer to chapters 12, 13 and 17 of JST Looms)	**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:
- Define insulator and its terminology.
- Explain the classification and stresses on insulators.
- Explain designing, manufacturing and testing standards of insulators.
- Suggest an insulator for a particular voltage.
- Explain physics of contamination and pollution flashover.
- Explain terminology of ice, its electrical characteristics, flashover process and icing test methods.
- Conduct tests on insulators. ■

Graduate Attributes (As per NBA):
Engineering Knowledge, Problem Analysis, Design / development of solutions, Conduct investigations of complex Problems, Engineers and society, Environment and sustainability, 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 Books

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

<table>
<tr><td colspan="4" align="center">M.TECH POWER SYSTEM ENGINEERING (EPS)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - II</td></tr>
<tr><td colspan="4" align="center">SWITCHING IN POWER SYSTEMS (Core Course)</td></tr>
<tr><td>Course Code</td><td>16EPS23</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" align="center">Credits - 04</td></tr>
</table>

Course objectives:

- To explain the practical aspects of switching, to describe the phenomena governing the switching process, the switching arc and the transient recovery voltage (TRV).
- To discuss faults in power systems, the switching of fault currents, correctly termed the making and breaking operations, resulting from various types of faults in power systems.
- To explain switching of loads: overhead lines, capacitor banks and shunt reactors operated under normal condition.
- To explain the calculation of the switching transients the switching processes in gaseous media.
- To discuss different circuit-breakers and to describes the switching in vacuum circuit breaker.
- To explain special switching situations and the appropriate devices used and the switching over voltages in systems and their mitigation. ■

<table>
<tr><td colspan="2">Module-1</td><td>Teaching Hours</td></tr>
<tr><td colspan="2">Switching in Power Systems: Introduction, Organization of this Book, Power-System Analysis, Purpose of Switching, The Switching Arc, Transient Recovery Voltage (TRV), Switching Devices, Classification of Circuit-Breakers.
Faults in Power Systems: Introduction, Asymmetrical Current, Short-Circuit Current Impact on System and Components, Fault Statistics.
Fault-Current Breaking and Making: Introduction, Fault-Current Interruption, Terminal Faults, Transformer-Limited Faults, Reactor-Limited Faults. ■</td><td rowspan="2">10</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">Fault-Current Breaking and Making (continued): Faults on Overhead Lines, Out-of-Phase Switching, Fault-Current Making.
Load Switching: Normal-Load Switching, Capacitive-Load Switching, Inductive-Load Switching. ■</td><td rowspan="2">10</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">Calculation of Switching Transients: Analytical Calculation, Numerical Simulation of Transients.
Current Interruption in Gaseous Media: Introduction, Air as an Interrupting Medium, Oil as an nterrupting Medium, Sulfur Hexafluoride (SF6) as an Interrupting Medium, SF6 – N2 Mixtures. ■</td><td rowspan="2">10</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">Gas Circuit-Breakers: Oil Circuit-Breakers, Air Circuit-Breakers, SF6 Circuit-Breakers.
Current Interruption in Vacuum: Introduction, Vacuum as an Interruption Environment, Vacuum Arcs.
Vacuum Circuit-Breakers: General Features of Vacuum Interrupters, Contact Material for Vacuum Switchgear, Reliability of Vacuum Switchgear, Electrical Lifetime, Mechanical Lifetime, Breaking Capacity, Dielectric Withstand Capability, Current Conduction, Vacuum Quality, Vacuum Switchgear for HV Systems.■</td><td rowspan="2">10</td></tr>
<tr><td>Revised Bloom's Taxonomy Level</td><td>L_1 – Remembering, L_2 – Understanding.</td></tr>
<tr><td colspan="3"></td></tr>
</table>

M.TECH POWER SYSTEM ENGINEERING (EPS)
16EPS23 SWITCHING IN POWER SYSTEMS (Core Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-5		**Teaching Hours**
Special Switching Situations: Generator-Current Breaking, Delayed Current Zero in Transmission Systems, Disconnector Switching, Earthing, Switching Related to Series Capacitor Banks, Switching Leading to Ferro resonance, Fault-Current Interruption Near Shunt Capacitor Banks, Switching in Ultra-High-Voltage (UHV) Systems, High-Voltage AC Cable System Characteristics, Switching in DC Systems, Distributed Generation and Switching Transients, Switching with Non-Mechanical Devices. **Switching Overvoltages and Their Mitigation:** Overvoltages, Switching Overvoltages, Switching-Voltage Mitigation, Mitigation by Controlled Switching. ■		**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:

- Explain switching, the phenomena governing the switching process, the switching arc and the transient recovery voltage (TRV).
- Discuss faults in power systems and the switching of fault currents.
- Explain switching of loads, overhead lines, capacitor banks and shunt reactors operated under normal condition.
- Calculate the switching transients.
- Explain the switching processes in gaseous media.
- Discuss different circuit-breakers.
- Discuss the switching in vacuum circuit breaker.
- Explain special switching situations, the appropriate devices used and the switching over voltages in systems and their mitigation. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Engineers and society, Environment and sustainability, 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	Switching in Electrical Transmission and Distribution Systems	Ren´e Smeets et al	Wiley	2015

M.TECH POWER SYSTEM ENGINEERING (EPS)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - II

FACTS CONTROLLERS (Core Course)

Course Code	16EPS24	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 SYSTEM ENGINEERING (EPS)
16EPS24 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 Internation al	2007

<table>
<tr><td colspan="4" align="center">M.TECH POWER SYSTEM ENGINEERING (EPS)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - II</td></tr>
<tr><td colspan="4" align="center">RESTRUCTURED POWER SYSTEMS (Elective Course)</td></tr>
<tr><td>Course Code</td><td>16EPS251</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" align="center">Credits - 03</td></tr>
</table>

Course objectives:

- To discuss the factors behind deregulation of the power sector and the after-effects of the same.
- To discuss established models of operational planning activities such as economic load dispatch, unit commitment and optimal power flow.
- To analyze different market models, and the operational planning issues specific to these, from the perspective of, both, the independent generator and the system operator.
- To explain transmission management issues such as pricing, security and congestion management and mechanisms by which these issues are addressed in the various forms of deregulated structures.
- To explain ancillary service management, their categorization, and pricing mechanisms as practiced in different electricity markets and Reactive power management an Ancillary Service.
- To explain basics of reliability analysis of power systems and deregulation. ■

<table>
<tr><td colspan="2">Module-1</td><td>Teaching Hours</td></tr>
<tr><td colspan="2">Deregulation of the Electricity Supply Industry: Introduction, Meaning of Deregulation, Background to Deregulation and the Current Situation around the World, Benefits from a Competitive Electricity Market, After Effects of Deregulation.
Power System Economic Operation Overview: Introduction, Economical Load Dispatch, Optimal Power Flow as a Basic Tool, Unit Commitment, Formation of Power Pools. ■</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">Power System Operation in Competitive Environment: Introduction, Role of Independent System Operator (ISO), Operational Planning Activities of ISO, Operational Planning Activities of a Genco. ■</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">Transmission Open Access and Pricing Issues: Introduction, Power Wheeling, Transmission Open Access, Cost Components in Transmission, Pricing of Power Transactions, Transmission Open Access and Pricing Mechanisms in Various Countries, Developments in International Transmission Pricing in Europe, Security Management in Deregulated Environment, Congestion Management in Deregulation. ■</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">Ancillary Services Management: Ancillary Services and Management in Various Countries, Reactive Power as an Ancillary Service. ■</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-5</td></tr>
<tr><td colspan="2">Reliability and Deregulation: Terminology, Reliability Analysis, Network Model, Reliability Costs, Hierarchical Levels, Reliability and Deregulation, Performance Indicators. ■</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"></td></tr>
</table>

M.TECH POWER SYSTEM ENGINEERING (EPS)
16EPS251 RESTRUCTURED POWER 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 factors behind deregulation of the power sector and the after-effects of the same.
- Discuss established models of operational planning activities; economic load dispatch, unit commitment and optimal power flow.
- Analyze different market models, and their operational planning issues.
- Explain transmission management issues; pricing, security and congestion management and their mechanisms.
- Explain ancillary service management, their categorization, and pricing mechanisms as practiced in different electricity markets.
- Explain Reactive power management an Ancillary Service.
- Explain basics of reliability analysis of power systems and deregulation. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Conduct investigations of complex Problems, Engineers and society, Environment and sustainability, 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	Operation of Restructured Power Systems	Kankar Bhattacharya et al	Kluwer Academic	2001

M.TECH POWER SYSTEM ENGINEERING (EPS) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - II			
SMART GRID (Elective Course)			
Course Code	16EPS252	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 smart grid and to explain the technologies required for it, the data communication architectures, switching techniques communication channels and technologies for smart grids.,
- To explain need of information security for smart grid and cyber security standards, smart metering, communication infrastructure and protocols for smart metering.
- To explain the automation equipment for distribution in smart grid, management system, faults that can occur in smart grid and voltage regulation
- To explain transmission system operation in smart grids and the power electronic converters used in smart grid.
- To introduce the power electronic equipment used for the control of bulk power flow and the energy storage technologies. ■

Module-1		**Teaching Hours**
The Smart Grid: Introduction, Smart Grid and Early initiatives, Overview of the technologies required for the Smart Grid. **Data communication:** Introduction, Dedicated and shared communication channels, Switching techniques, Communication channels, Layered architecture and protocols. **Communication technologies for the Smart Grid:** Introduction, Communication technologies, Standards for information exchange. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
Module-2		
Information security for the Smart Grid: Introduction, Encryption and decryption, Authentication, Digital signatures, Cyber security standards. **Smart metering and demand-side integration:** Introduction, Smart metering, Smart meters: An overview of the hardware used, Communications infrastructure and protocols for smart metering, Demand-side integration. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
Module-3		
Distribution automation equipment: Introduction, Substation automation equipment, Faults in the distribution system, Voltage regulation. **Distribution management systems:** Introduction, Data sources and associated external systems, Modelling and analysis tools, Applications. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
Module-4		
Transmission system operation: Introduction, Data sources, Energy management systems, Wide area applications, Visualisation techniques. **Power electronic converters:** Introduction, Current source converters, Voltage source converters. **Power electronics in the Smart Grid:** Introduction, Renewable energy generation, Fault current limiting, Shunt compensation, Series compensation. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

M.TECH POWER SYSTEM ENGINEERING (EPS)
16EPS252 SMART GRID (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-5		**Teaching Hours**
Power electronics for bulk power flows: Introduction, FACTS, HVDC. **Energy storage**: Energy storage technologies, Case study 1: Energy storage for wind power, Case study 2: Agent-based control of electrical vehicle battery charging. ■		**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 smart grid, the technologies required for it, the data communication architectures.
- Explain switching techniques, communication channels and technologies for smart grids.
- Explain need of information security for smart grid and cyber security standards.
- Discuss smart metering, and protocols for smart metering.
- Explain the automation equipment for distribution in smart grid, management system, faults that can occur in smart grid and voltage regulation.
- Explain transmission system operation in smart grids and the power electronic converters used in smart grid.
- Discuss about the power electronic equipment used for the control of bulk power flow and the energy storage technologies. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Modern Tool Usage, Engineers and society, Environment and sustainability, Ethics, 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	Smart Grid Technology and Applications	Janaka Ekanayake et al	Wiley	2012

M.TECH POWER SYSTEM ENGINEERING (EPS) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - II			
POWER QUALITY PROBLEMS AND MITIGATION (Elective Course)			
Course Code	16EPS253	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 SYSTEM ENGINEERING (EPS)
16EPS253 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 SYSTEM ENGINEERING (EPS) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - II			
SUBSTATION AUTOMATION SYSTEMS (Elective Course)			
Course Code	16EPS254	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 a brief review evolution of Substation Automation System, explain its purpose as an essential part of the substation, the effects of Standard IEC 61850 on different stages of SAS projects
- To explain constructive and functional features of equipment that makes up the primary power circuit.
- To explain the characteristics of Intelligent Electronic Devices used for control and monitoring and to describe briefly certain phenomenon which affect the physical/functional integrity of such devices.
- To provide an overview of how the features and functions of devices installed into the main control house are used for controlling and monitoring the substation as a whole
- To explain different SAS functionalities including switching commands and constraints like interlocking and blocking conditions.
- To explain the set of signals coming from different substation components that need to be managed by the SAS, and the engineering of SAS.
- To explain the communication process with remote control center and to describe the network topology, quality requirements and cyber-security considerations, tests to carry out of SAS and commissioning process.
- To explain the scope and sequence of training programs addressed to utilities personnel, how to deal with SAS projects, tips for quality management, resources to be used and methodology to be followed for the engineering process according to Standard IEC 61850, and future technological trends. ■

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

Module-1		**Teaching Hours**
Evolution of Substation Automation Systems (SASs): Emerging Communication Technologies, Intelligent Electronic Devices (IEDs), Networking Media, Communication Standards. **Main Functions of Substation Automation Systems:** Control Function, Monitoring Function, Alarming Function, Measurement Function, Setting and Monitoring of Protective Relays, Control and Monitoring of the Auxiliary Power System, Voltage Regulation. **Impact of the IEC 61850 Standard on SAS Projects:** Impact on System Implementation Philosophy, Impact on User Specification, Impact on the Overall Procurement Process, Impact on the Engineering Process, Impact on Project Execution, Impact on Utility Global Strategies, The Contents of the Standard, Dealing with the Standard. **Switchyard Level, Equipment and Interfaces:** Primary Equipment, Medium and Low Voltage Components, Electrical Connections between Primary Equipment, Substation Physical Layout, Control Requirements at Switchyard Level. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
Module-2		
Bay Level: Components and Incident Factors: Environmental and Operational Factors, Insulation Considerations in the Secondary System, Switchyard Control Rooms, Attributes of Control Cubicles, The Bay Controller (BC), Other Bay Level Components, Process Bus. **Station Level: Facilities and Functions:** Main Control House, Station Controller, Human Machine Interface HMI, External Alarming, Time Synchronization Facility, Protocol Conversion Task, Station Bus, Station LAN. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	

M.TECH POWER SYSTEM ENGINEERING (EPS)
16EPS254 SUBSTATION AUTOMATION SYSTEMS (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-3		Teaching Hours
System Functionalities: Control Function, Monitoring Function, Protection Function, Measuring Function, Metering Function, Report Generation Function, Device Parameterization Function. **System Inputs and Outputs:** Signals Associated with Primary Equipment, Signals Associated with the Auxiliary Power System, Signals Associated with Collateral Systems. **System Engineering:** Overall System Engineering, Bay Level Engineering, Station Level Engineering, Functionalities Engineering, Auxiliary Power System Engineering, Project Drawings List, The SAS Engineering Process from the Standard IEC 61850 Perspective. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
Module-4		
Communication with the Remote Control Center: Communication Pathway, Brief on Digital Communication, Overview of the Distributed Network Protocol (DNP3). **System Attributes:** System Concept, Network Topology, Redundancy Options, Quality Attributes, Provisions for Extendibility in Future, Cyber-Security Considerations, SAS Performance requirements. **Tests on SAS Components:** Type Tests, Acceptance Tests, Tests for Checking the Compliance with the Standard IEC 61850. **Factory Acceptance Tests (FATs):** Test Arrangement, System Simulator, Hardware Description, Software Identification, Test Instruments, Documentation to be Available, Checking System Features, Planned Testing Program for FAT, Nonstructured FATs, After FATs. **Commissioning Process:** Hardware Description, Software Identification, Test Instruments, Required Documentation, Engineering Tools, Spare Parts, Planned Commissioning Tests, Nonstructured Commissioning Tests, List of Pending Points, Re-Commissioning. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
Module-5		
Training Strategies for Power Utilities: Project-Related Training, Corporate Training. **Planning and Development of SAS Projects:** System Specification, Contracting Process, Definition of the Definitive Solution, Design and Engineering, System Integration, Factory Acceptance Tests, Site Installation, Commissioning Process, Project Management, Security Issues, Documentation and Change Control. **Quality Management for SAS Projects:** Looking for Quality- in Component Capabilities and Manufacturing, during the Engineering Stage, in the Cubicle Assembly Stage, during FAT, during Installation and Commissioning, Use of Appropriate Device Documentation. **SAS Engineering Process According to Standard IEC 61850:** SCL Files, Engineering Tools, Engineering Process. **Future Technological Trends:** Toward the Full Digital Substation, Looking for New Testing Strategies on SAS Schemes, Wide Area Control and Monitoring Based on the IEC/TR 61850–90–5, Integration of IEC 61850 Principles into Innovative Smart Grid Solutions. ■		**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 evolution of Substation Automation System, its purpose as an essential part of the substation.
- Explain constructive and functional features of equipment that make up the primary power circuit.
- Explain the characteristics of Intelligent Electronic Devices (IEDs) used for control and monitoring.
- Explain SAS functionalities including switching commands and constraints like interlocking and blocking conditions.

M.TECH POWER SYSTEM ENGINEERING (EPS)
16EPS254 SUBSTATION AUTOMATION SYSTEMS (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Course outcomes (continued):

- Explain the set of signals coming from different substation components that need to be managed by the SAS, and the engineering of SAS.
- Explain the communication network topology in a substation and its working.
- Explain tests to carry out of SAS and commissioning process.
- Explain the scope and sequence of training programs addressed to utilities personnel to deal with SAS projects. ■

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.

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	Substation Automation Systems Design and implementation	Evelio Padilla	Wiley	2016

M.TECH POWER SYSTEM ENGINEERING (EPS) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - II			
POWER SYSTEM LABORATORY-II			
Course Code	16EPSL26	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 model a power system and perform transient stability and small signal stability studies.
- To model automatic voltage regulator and governor to study their effect on stability
- To study dynamic var compensation, capacitor bank switching studies, voltage control and inrush current.
- To model the transmission line, lighting impulse and surge arrestor, CT and CVT using EMTP for transient analysis.
- To model the circuit breaker and study the current chopping and suppression of over voltage using surge arrestor and RC network. ■

Sl. NO	Experiments
1	Transient stability studies for a given system having minimum 10 buses, machines and an infinite grid to determine (i) Critical clearing time (ii) Natural frequency of oscillations of electro-mechanical system considering classical representation of the machine and detailed modelling (sub-transient model) of the machine.
2	The AVR and Governor modelling and their effect on system stability.
3	Eigen value computation and small signal stability studies for a given power system with at least 3 machines and 10 buses using IEEE-Type 1 AVR and turbine-governor models.
4	Dynamic VAR compensation and voltage control using shunt SVC.
5	Frequency and voltage dependency model of the load and under frequency load shedding.
6	Capacitor bank switching studies and control of over voltage and inrush current.
7	Electromagnetic transient analysis during charging of a 400 kV, 300 km long line (i) without pre-insertion resistance (ii) With pre-insertion resistance (iii) With shunt reactor at the receiving end of the line.
8	Vacuum circuit breaker current chopping phenomenon and suppression of over voltage using (i) Surge arrestor (ii) R-C network.
9	Lightning impulse model and surge arrestor modelling studies using electromagnetic transient analysis for a given transmission line.
10	CT and CVT transients modelling using electromagnetic transient analysis.

Revised Bloom's Taxonomy Level	L_1 - Remembering, L_2 - Understanding, 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:

- Model a power system to perform transient stability and small signal stability studies.
- Model automatic voltage regulator and governor to study their effect on stability.
- Explain dynamic var compensation, capacitor bank switching studies, voltage control and inrush current.
- Model the transmission line, lighting impulse and surge arrestor, CT and CVT using EMTP for transient analysis.
- Model the circuit breaker to study the current chopping and suppression of over voltage using surge arrestor and RC network.■

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 SYSTEM ENGINEERING (EPS) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - II			
SEMINAR			
Course Code	16EPS27	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 16EPS27 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 SYSTEM ENGINEERING (EPS)
CHOICE BASED CREDIT SYSTEM (CBCS)
(Total number of credits prescribed for the programme - 85)

III SEMESTER

Sl. No	Subject Code	Title	Teaching Hours /Week		Examination				Credits
			Theory	Practical/ Field work/ Assignment	Duration in hours	I.A. Marks	Theory/ Practical Marks	Total Marks	
1	16EPS31	Seminar / Presentation on Internship. (After 8 weeks from the date of commencement)	--	--	--	25	--	25	20
2	16EPS32	Report on Internship	--	--	--	25	--	25	
3	16EPS33	Evaluation and Viva-Voce of Internship	--	--	--	--	50	50	
4	16EPS34	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 SYSTEM ENGINEERING (EPS)
CHOICE BASED CREDIT SYSTEM (CBCS)
(Total number of credits prescribed for the programme - 85)

IV SEMESTER

Sl. No	Subject Code	Title	Teaching Hours /Week		Examination				Credits
			Theory	Practical/ Field work/ Assignment	Duration in hours	I.A. Marks	Theory/ Practical Marks	Total Marks	
1	16EPS41	HVDC Power Transmission	04	--	03	20	80	100	4
2	16EPS42X	Elective - 3	03	--	03	20	80	100	3
3	16EPS43	Evaluation of Project phase - 2	--	--	--	50	-	50	3
4	16EPS44	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

Courses under Code 16EPS42X	Title
16EPS421	Power System Reliability
16EPS422	Wide Area Measurements and their Applications
16EPS423	Multi-Terminal DC Grids
16EPS424	Integration of Renewable Energy

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 SYSTEM ENGINEERING (EPS)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - IV

HVDC POWER TRANSMISSION (Core Course)

Course Code	16EPS41	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	Teaching Hours
Module-1	
HVDC Technology: Introduction, Advantages of HVDC Systems, HVDC System Costs, Overview and Organization of HVDC Systems, Review of the HVDC System Reliability, HVDC Characteristics and Economic Aspects. **Power Conversion:** Thyristor, 3-Phase Converter, 3-Phase Full Bridge Converter, 12-Pulse Converter. ■	**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 SYSTEM ENGINEERING (EPS)
16EPS41 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	2nd Edition, 1998
4	HVDC Transmission	S. Kamakshaiah et al	Mc Graw Hill	2011
5	HVDC and FACTs Controllers; Applications of Static Converters in Power Systems	Vijay K Sood	BSP Books	2013
6	HVDC Power Transmission Systems	K. R. Padiyar	New Age International	2012

M.TECH POWER SYSTEM ENGINEERING (EPS) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - IV			
POWER SYSTEM RELIABILITY (Elective Course)			
Course Code	16EPS421	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 the students' knowledge on how to use reliability analysis as a tool for decision support during planning, design, operation and maintenance of electric power systems in particular electrical distribution systems. ■

Module-1		Teaching Hours
Introduction: Background, Changing scenario, Probabilistic reliability criteria, Statistical and probabilistic measures, Absolute and relative measures, Methods of assessment, Concepts of adequacy and security, System analysis. **Generating capacity---basic probability methods:** Introduction, The generation system model, Loss of load indices, Equiva1ent forced outage rate, Capacity expansion analysis, Scheduled outages, Evaluation methods on period bases, Load forecast uncertainty, Forced outage rate uncertainty, Loss of energy indices, Practical system studies, Problems. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
Module-2		
Generating capacity-frequency and duration method: Introduction, The generation model, System risk indices, Practical system studies, Problems. **Interconnected systems:** Introduction, Probability array method in two interconnected systems, Equivalent assisting unit approach to two interconnected systems, Factors affecting the emergency assistance available through the interconnections, Variable reserve versus maximum peak load reserve, Reliability evaluation in three interconnected systems, Multi-connected systems, Frequency and duration approach, Problems. ■		**08**
Revised Bloom's Taxonomy Level	L_1 - Remembering, L_2 - Understanding, L_3 - Applying, L_4 – Analysing.	
Module-3		
Operating reserve: General concepts, PJM method, Extensions to PJM method, Modified PJM method, Postponable outages, Security function approach, Response risk, Interconnected systems, Problems. **Composite generation and transmission systems:** Introduction, Radial configurations, Conditional probability approach, Network configurations, State selection, System and load point indices, Application to practica1 systems, Data requirements for composite system reliability evaluation, Problems. ■		**08**
Revised Bloom's Taxonomy Level	L_1 - Remembering, L_2 - Understanding, L_3 - Applying, L_4 – Analysing.	
Module-4		
Distribution systems--basic techniques and radial networks: Introduction, Evaluation techniques, Additional interruption indices, Application to radial systems, Effect of lateral distributor protection, Effect of disconnects, Effect of protection failures, Effect of transferring loads, Probability distributions of reliability indices, Problems. **Distribution systems--parallel and meshed networks:** Introduction, Basic evaluation techniques, Inc1usion busbar failures, Inc1usion of scheduled maintenance, Temporary and transient failures, Inclusion of weather effects, Common mode failures, Common mode failures and weather effects, Inclusion of breaker failures, Problems. ■		**08**
Revised Bloom's Taxonomy Level	L_1 - Remembering, L_2 - Understanding, L_3 - Applying, L_4 – Analysing.	

M.TECH POWER SYSTEM ENGINEERING (EPS)
16EPS421 POWER SYSTEM RELIABILITY (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-5	**Teaching Hours**
Substations and switching stations: Introduction, Effect of short circuits and breaker operation, Operating and failure states of system components, Open and short circuit failures, Active and passive failures, Malfunction of normally closed breakers, Numerical analysis of typical substation, Malfunction of alternative supplies, Problems. **Plant and station availability:** Generating plant availability, Derated states and auxiliary systems, Allocation and effect of spares, Protection systems, HVDC systems, Problems. ■	**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:

- Define terminology of reliability.
- Explain probability concepts for generating capacity reliability evaluation.
- Explain various concepts and evaluation techniques that can be used to assess operational risk
- Evaluate composite system reliability.
- Evaluate the reliability of complex distribution systems.
- Perform power system analysis including different aspects such as need, availability, adequacy. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Design / development of solutions, Conduct investigations of complex Problems, Engineers and society, Environment and sustainability, 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	Reliability Evaluation of Power Systems	Roy Billinton et al	Elsevier	2nd Edition, 2015

M.TECH POWER SYSTEM ENGINEERING (EPS)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - IV

WIDE AREA MEASUREMENTS AND THEIR APPLICATIONS (Elective Course)

Course Code	16EPS422	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 define a phasor, and explain the method of representing a phasor using Fourier series and Fourier transforms, sampling the data and discrete Fourier transform and estimation of nominal frequency inputs.
- To explain phasor estimation at off nominal frequency inputs in power systems and post processing for estimates.
- To explain the changes in power system frequency due to responses to load generation imbalances and when the power system is in a quasi-steady state and is operating with a frequency which may be different from its nominal value.
- To explain certain practical implementation aspects of the PMUs and the architecture of the data collection and management system necessary for efficient utilization of the data provided by the PMUs.
- To explain the investigation of the nature of PMU response to various power system transients.
- To explain the history of state estimation, various methods for state estimation with phasor measurements and the control of power system devices with phasor feedback.
- To explain improved line protection using phasor measurements from the remote ends of the line and propagation of electromechanical wave and its effect on protection system. ■

Module-1	Teaching Hours
Phasor Measurement Techniques: Introduction, Historical overview, Phasor representation of sinusoids, Fourier series and Fourier transform, Sampled data and aliasing, Discrete Fourier transform (DFT), Leakage phenomena. **Phasor Estimation of Nominal Frequency Inputs:** Phasors of nominal frequency signals, Formulas for updating phasors, Effect of signal noise and window length, Phasor estimation with fractional cycle data window, Quality of phasor estimate and transient monitor, DC offset in input signals, Non-DFT estimators. ■	**08**
Revised Bloom's Taxonomy Level: L_1 - Remembering, L_2 - Understanding, L_3 – Applying.	

Module-2	
Phasor Estimation at Off-Nominal Frequency Inputs: Types of frequency excursions found in power systems, DFT estimate at off-nominal frequency with a nominal frequency clock, Post-processing for off-nominal frequency estimates, Phasor estimates of pure positive sequence signals, Estimates of unbalanced input signals, Sampling clocks locked to the power frequency, Non-DFT type phasor estimators. **Frequency Estimation:** Overview of frequency measurement, Frequency estimates from balanced three phase inputs, Frequency estimates from unbalanced inputs, Nonlinear frequency estimators, Other techniques for frequency measurements. ■	**08**
Revised Bloom's Taxonomy Level: L_1 - Remembering, L_2 - Understanding, L_3 – Applying.	

Module-3	
Phasor Measurement Units and Phasor Data Concentrators: Introduction, A generic PMU, The global positioning system, Hierarchy for phasor measurement systems, Communication options for PMUs, Functional requirements of PMUs and PDCs. **Transient Response of Phasor Measurement Units:** Introduction, Nature of transients in power systems, Transient response of instrument transformers, Transient response of filters Transient response during electromagnetic transients Transient response during power swings. ■	**08**
Revised Bloom's Taxonomy Level: L_1 - Remembering, L_2 - Understanding, L_3 – Applying.	

M.TECH POWER SYSTEM ENGINEERING (EPS)
16EPS422 WIDE AREA MEASUREMENTS AND THEIR APPLICATIONS (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-4		**Teaching Hours**
State Estimation: History-Operator's load flow, Weighted least square, Static state estimation, Bad data detection, State estimation with Phasors measurements, Calibration, Dynamic estimators. **Control with Phasor Feedback:** Introduction, Linear optimal control, Linear optimal control applied to the nonlinear problem, Coordinated control of oscillations, Discrete event control. ■		**08**
Revised Bloom's Taxonomy Level	L_1 - Remembering, L_2 - Understanding, L_3 – Applying.	
Module-5		
Protection Systems with Phasor Inputs: Introduction, Differential protection of transmission lines, Distance Relaying of multiterminal transmission lines, Adaptive protection, Control of backup relay performance, Intelligent islanding, Supervisory load shedding. **Electromechanical Wave Propagation:** Introduction, The Model, Electromechanical telegrapher's equation, Continuum voltage magnitude, Effects on protection systems, Dispersion, Parameter distribution. ■		**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 the method of representing a phasor using Fourier series and Fourier transforms, sampling the data and discrete Fourier transform.
- Explain phasor estimation at nominal and off nominal frequency inputs in power systems and post processing for estimates.
- Explain the changes in power system frequency due to responses to load generation imbalances in power system.
- Explain implementation aspects of the PMUs, the architecture of the data collection.
- Explain management system necessary for efficient utilization of the data provided by the PMUs.
- Explain state estimation, methods for state estimation with phasor measurements and the control of power system devices with phasor feedback.
- Explain line protection using phasor measurements. ■

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 Book

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

M.TECH POWER SYSTEM ENGINEERING (EPS) CHOICE BASED CREDIT SYSTEM (CBCS) SEMESTER - IV			
MULTI-TERMINAL DC GRIDS (Elective Course)			
Course Code	16EPS423	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 SYSTEM ENGINEERING (EPS)
16EPS423 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.
- Explain control modes and basics of voltage sourced converters.
- Simulate AC- MTDC grids for their analysis
- Explain the concept of power sharing in MTDC grid, load flow solution and post contingency operation.
- 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 SYSTEM ENGINEERING (EPS)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - IV

INTEGRATION OF RENEWABLE ENERGY (Elective Course)

Course Code	16EPS424	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 two fundamental architectures, namely DC architecture and AC architecture for integration of smart grid distributed generation and the inverter control voltage and current in distributed generation systems;
- To discuss parallel operation of inverters in distributed generation systems and power converter topology for distributed generation systems
- To explain voltage and current control of a three-phase four wire distributed generation in island mode.
- To explain the power flow control of a single distributed generating unit.
- To explain robust stability analysis of voltage and current control for distributed generation systems and PWM rectifier control for three-phase distributed generation system. ■

Module-1		Teaching Hours
Smart Grid Distributed Generation Systems: Introduction, DC Architecture for Design of a 2 MVA PV Station, PV Modules, Architecture for design of a 2 MVA PV Station, DG System Operating as Part of Utility Power System Power System Reactive Power (VAR) Control, An Inverter is also a Three Terminal Device, The Smart Grid PV –UPS DG System, The Smart Grid Split DC Bus UPS – PV DG System, The Island Mode of Operation, The Parallel Operation of Inverters, The Inverter Operating as steam Unit, The Problem of Power Quality. **Inverter Control Voltage and Current Distributed Generation Systems:** Power converter system, Control Theory, Control System Development, Step-By-Step Control Flow Explanations.■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
Module-2		
Parallel Operation of Inverters in Distributed Generation Systems: Introduction, Distributed Energy System Description, DGS Control Requirements, Distributed Generation System Modelling, Control System Design, Proposed Load Sharing Control Algorithm, Simulation Results. **Power Converter Topologies for Distributed Generation Systems:** Introduction, Distributed Generation Systems, Voltage and Current Control of Individual Inverters in Island Mode, The System Topology, Newton–Raphson Method. ■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
Module-3		
Voltage and Current Control of three-Phase Four-Wire Distributed Generation (DG) Inverter in Island Mode: The Plant Modelling, The Basic Mathematical Model, Transform the Model into Stationary Reference Frame, Convert to Per-Unit System, Control System Development, Design of the Discrete-Time Sliding Mode Current Controller, Design of the Robust Servomechanism Voltage Controller, Limit the Current Command, A Modified Space Vector PWM, Performances and Analysis—Frequency Domain Analysis.■		**08**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
Module-4		
Voltage and Current Control of three-Phase Four-Wire Distributed Generation (DG) Inverter in Island Mode (continued): Experimental Results—The Experimental Setup, The Robust Stability: Basic Ideas About Uncertainty, Robust Stability, and M – Analysis.		**08**

M.TECH POWER SYSTEM ENGINEERING (EPS)
16EPS424 INTEGRATION OF RENEWABLE ENERGY (Elective Course) (continued)
CHOICE BASED CREDIT SYSTEM (CBCS)

Module-4 (continued)		**Teaching Hours**
Power Flow Control of a Single Distributed Generation Unit: Introduction, Control System, Voltage and Current Control, Real and Reactive Power Control Problems, The Conventional Integral Control, The Stability Problem, Newton–Raphson Parameter Estimation and Feedforward Control Newton–Raphson Parameter Identification, Harmonic Power Control, Simulation Results, Experimental Results. ■		
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding.	
Module-5		
Robust Stability Analysis of Voltage and Current Control for Distributed Generation Systems: Introduction, The Stability Problem, Robust Stability Analysis using Structured Singular Value μ, Tuning the Controller Performance. **PWM Rectifier Control for Three-Phase Distributed Generation System:** Introduction, System Analysis, The Control Strategy, Simulation Results, Experimental Results. ■		**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 the architectures for integration of smart grid distributed generation.
- Explain the control voltage and current in distributed generation systems.
- Discuss parallel operation of inverters in distributed generation systems and power converter topology for distributed generation systems.
- Explain voltage and current control of a three-phase four wire distributed generation in island mode.
- Explain the power flow control of a single distributed generating unit.
- Perform robust stability analysis of distributed generation systems.
- Explain PWM rectifier control for three-phase distributed generation system. ■

Graduate Attributes (As per NBA):

Engineering Knowledge, Problem Analysis, Design / development of solutions, 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	Integration of Green and Renewable Energy in Electric Power Systems	Ali Keyhani	Wiley	2010

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