ANNXURE- II

Post Graduate Programme

M. Tech.
in
Power Systems

Curriculum
(as per NEP)

सरदार वल्लभभाई राष्ट्रीय प्रोद्योगिकी संस्थान, सूरत

SARDAR VALLBHBHAI NATIONAL INSTITUTE OF TECHNOLOGY, SURAT

विधुत इंजीनियरिंग विभाग

DEPARTMENT OF ELECTRICAL ENGINEERING

SARDAR VALLABHBHAI NATIONAL INSTITUTE OF TECHNOLOGY, SURAT
DEPARTMENT OF ELECTRICAL ENGINEERING
Teaching Scheme: M.Tech. in Power Systems

Sr. No.	Subject	Code	Scheme L-T-P	Exam Scheme			Credits (Min.)	Notional hours of Learning (Approx.)
				Th. Marks	T Marks	P Marks		
	First Semester							
1	Computer Aided Power System Analysis (Core-1)	EEPS101	3-1-2	100	25	50	05	100
2	Power System Protection (Core-2)	EEPS103	3-1-2	100	25	50	05	100
3	Restructuring in Power Systems	EEPS105	3-1-0	100	25	00	04	70
4	Elective-1	EEPS1XX	3-0-0	100	-	-	03	55
5	Elective-2	EEPS1XX	3-0-0	100	-	-	03	55
						Total	**20**	**380**
6	Vocational Training / Professional Experience (Optional) (Mandatory for Exit)	EEPE91 EEPE93	0-0-10				5	200 (20 x 10)
	Second Semester							
1	Power System Dynamics and Control (Core-IV)	EEPS102	3-1-2	100	25	50	05	100
2	Applications of Power Electronics in Power Systems (Core-V)	EEPS104	3-1-2	100	25	50	05	100
3	Elective-3	EEPS1XX	3-0-0	100	-	-	03	55
4	Elective-4	EEPS1XX	3-0-0	100	-	-	03	55
5	Institute Elective	EEPS1XX	3-0-0	100			03	55
6	Mini Project	EEPS106	0-0-4	00	00	50	02	70
						Total	**21**	**435**
7	Vocational Training / Professional Experience (Optional) (Mandatory for Exit)	EEPS92 EEPS94	0-0-10				5	200 (20 x 10)
	Third Semester							
1	MOOC course- I* (Swayam/NPTEL)	Φ-NPTEL-SWM-301-304/ NPTEL-SWM401-404	3/4-0-0	100	00	00	3/4	70/80
2	MOOC course- II* (Swayam/NPTEL)	Φ-NPTEL-SWM-301-304/ NPTEL-SWM401-404	3/4-0-0	100	00	00	3/4	70/80

3	Dissertation Preliminaries	EEPS295	0-0-28	-	-	350$	14	560
						Total	**20-22**	**700-720**
	Fourth Semester							
1	Dissertation	EEPS296	0-0-40	-	-	600$	20	800
						Total	20	800

List of Elective Subjects

Elective-1

Sr. No	Code	Subject
01	EEPS111	Digital Signal Processing
02	EEPS113	Power Electronics
03	EEPS115	Distributed Generation
04	EEPS117	Power Quality
05	EEPS119	Microcontroller Based System Design

Elective-2

Sr. No	Code	Subject
01	EEPS131	Power System Transients
02	EEPS133	Forecasting and Planning Methods
03	EEPS135	Operation and Analysis of Distribution System
04	EEPS137	Electrical Machine for Renewable Energy Generation
05	EEPS139	System Theory

Elective-3

Sr. No	Code	Subject
01	EEPS112	High Voltage Engineering & EHV AC Transmission
02	EEPS114	Electric Vehicle Technology
03	EEPS116	Cryptography and Cyber Security
04	EEPS118	Advance Power Converters for Renewable Energy Applications
05	EEPS120	Insulation Engineering

Elective-4

Sr. No	Code	Subject
01	EEPS142	Renewable Energy Sources
02	EEPS144	HVDC Transmission
03	EEPS146	Energy Audit
04	EEPS148	Advanced Energy Storage Devices and Applications
05	EEPS150	Wide Area Power System Control

Institute Elective

Sr. No	Code	Subject
01	EEPS172	Advanced Optimization Methods
02	EEPS174	Advanced Numerical Methods
03	EEPS176	Artificial Intelligence and Machine Learning
04	EEPS178	Reliability Evaluation of Electrical Systems
05	EEPS180	Energy Storage and Management

M. Tech. Power System, Ist year, Semester I

COMPUTER AIDED POWER SYSTEM ANALYSIS

EEPS101

L	T	P	Credit
3	1	2	05

1. Course Outcomes (COs):

At the end of the course, the students will be able to:

CO1	To formulate Power flow problems.
CO2	Solving power flow problems by various methods.
CO3	Formulate and solve the optimum power flow problem.
CO4	Analysis of faulted power systems.
CO5	Contingency analysis of power systems with single and multiple contingencies.
CO6	Application of Least Square method for power system state estimation.

2. Syllabus

- **Mathematical preliminaries** **04 hrs.**
- LU Decomposition methods: Crout, Shipley, Dolittle, Sparse matrix computations
- **Power Flow Analysis** **09 hrs.**
  Power flow problem formulation, Construction of Ybus matrix including magnetic coupled lines and transformer by various methods: Direct, Primitive matrices, Graph Theory, Near-optimal ordering of bus number, Gauss-Seidel method, Newton-Raphson method, Fast Decoupled method, DC load flow, AC-DC load flow, distribution system load flow.
- **Economic Dispatch and Optimum Power Flow** **06 hrs.**
  Classical optimization method with and without constraints, Lossless Generation Dispatch, Economic Dispatch including Losses, Optimum Power Flow Formulation and its solution by Gradient and Newton's method.
- **Short Circuit Analysis** **09 hrs.**
  Thevenin's impedance at bus and between two buses, Modifications to existing Zbus, Zbus algorithm to construct Zbus matrix, Power Invariant transformation, Balanced fault analysis using conventional method and Zbus, Selection circuit breaker, Symmetrical components and sequence networks of various components, Analysis of system with unbalanced faults (LG, LL, LLG) using Zbus matrix, open conductor faults
- **Power System Contingency Analysis** **09 hrs.**
  Concept of compensating currents for simulation of adding and removing multiple lines, Analysis of single contingencies, Analysis of multiple contingencies, contingency analysis by dc model
- **Power System State Estimation** **08 hrs.**
  Need for power system state estimation, Least Squares method, Basics of Statistics, Test for Bad data, the structure and formation of Hx, Line only algorithm

Total Hours-45

3. Books Recommended:

1 Power System Analysis by John J. Grainger and William D. Stevenson, Tata McGraw Hill Education Private Limited, New Delhi, Edition 2003
2 Power Generation Operation and Control by Allen J. Wood and Bruce F. Wollenberg, John Wiley & Sons Inc, Second Edition
3 Power System Analysis by Hadi Saadat, Tata McGraw Hill Publishing Company Limited, New Delhi, Edition 2002

4 Power System Analysis and Design by J. Duncan Glover, Mulukutla S. Sarma and Thomas J. Overby, Thomson Corporation, Fourth Edition
5 Power System Analysis by Arthur R. Bergen and Vijay Vittal, Pearson Education India, Second Edition
6 Computer analysis of power systems by Arrillaga, J and Arnold C.P, John Wiley and Sons, New York, 1997
7 Computer Techniques in Power System Analysis by Pai M. A., Tata McGraw hill, New Delhi, 2006
8. Computational methods for Electric Power Systems by Mariesa L. Crow, Second Edition, CRC Press

4. List of Experiments.

1 Solution of Linear Algebric equations using Gauss elimination, Crout's, Dolittle and Shipley method.
2 Solution of Linear Electrical circuit by Cut set and Tie set method.
3 Generalized program for determing Ybus of given netwrok.
4 Generalized program for determing load flow of given netwrok using G-S method.
5 Generalized program for determing load flow of given netwrok using N-R method.
6 Generalized program for determing load flow of given netwrok using FDLF method.
7 Load flow simulation of given network in ETAP.
8 Load flow simulation of given network in POWERWORLD.
9 Optimum Power Flow using MATPOWER.
10 Generalized program for determing Zbus of given netwrok.
11 Generalized program for conducting short circuit analysis on given network.
12 Short circuit analysis of given network using ETAP, POWERWORLD.
13 Generalized program for conducting State-Estimation on given network.

Note: Tutorials will be conducted separately for 15 hours

M. Tech. Power System, Ist year, Semester I

POWER SYSTEM PROTECTION

EEPS103

L	T	P	Credit
3	1	2	05

1. **Course Outcomes (COs):**

At the end of the course, the students will be able to:

CO1	Analyse power system faults for balanced and unbalanced conditions.
CO2	Apply the fundamental principles of protective devices for the protection of various electrical items.
CO3	Describe current and voltage transformers and their impact on protection scheme performance.
CO4	Identify, apply, and calculate settings for power lines, transformer, generator, and bus bar protection schemes.
CO5	Illustrate the concepts of microprocessor based protective relays and digital relaying algorithms.

2. **Syllabus**

- **Review Of Principles of Power System Protection** **04 Hrs.**
  General philosophy of protection, Relay terminology, Review of Relay characteristics, Classification of Relays, characteristics and operating equation.
- **Instrument Transformer for Relaying** **04 Hrs.**
  Performance of conventional CT/PT as well as capacitive voltage transformers. Principle of operation of magneto optic CT/ PT. Standards, effect on relaying philosophy.
- **Network Protection with Renewable Sources** **07 Hrs.**
  Fault characteristics of renewable Sources, Protection of distribution and transmission networks in the presence of renewables
- **Apparatus Protection** **15 Hrs.**
  Protection of generator, motor, transformer, transmission line and bus-bar. Relay co-ordination. Pilot wire protection, carrier current protection. Testing of relay.
- **Philosophy Of Numerical Relaying** **15 Hrs.**
  Introduction, Anti –aliasing Filters, sampling, Measurements principles using Fourier and other algorithms and its application for implementation of various numerical relays. Algorithms for transmission line, transformer & bus bar protection; out-of-step relaying, Introduction to adaptive relaying & wide area measurements.

Total Hours-45

Note: Tutorials will be conducted separately for 15 hours

3. **Books Recommended:**

1 Bhuvanesh Oza, N.C. Nair, R.P.Mehta, V.H.Makwana "Power System Protection and Switchgear", Tata 2010
2 Y.G. Paithankar, S.R. Bhide,"Fundamentals of Power System Protection" PHI,2008
3 J. Lewis Blackburn,'Protective Relaying' Marcel Dekker INC. 1997
4 Arun G. Phadke, James S. Thorp,"Computer Relaying For Power Systems" John Willey & sons
5 Badri Ram, D N Vishwakarma, " Power System Protection and Switchgear', Tata Mc Graw Hill, 2005

6 Prof. S. A. Soman,"Web course on Power System Oritection" on the website http://nptel.iitm.ac.in

4. List of Experiments

1 To study and simulate the generation of standard impulse voltage using MATLAB Simulink.
2 (a) To simulate magnetizing inrush current of 1-phase transformer on MATLAB Simulink.
(b) To observe magnetizing inrush current waveform of transformer.
3 (a) To study transient by applying sudden short-circuit on 3-phase synchronous generator using MATLAB 7 Simulink.
(b) To observe the short circuit current by applying sudden short-circuit on 3-phase synchronous generator.
4 To study and obtain characteristics of IDMT numerical relay for over & under voltage protection.
5 To study the coordination of IDMT relays for the protection of radial feeder.
6 To study the concepts of directional relay and its application in parallel feeder protection
7 To study different protections of 3-phase induction motor using numerical relay.
8 To study different protection schemes of generator protection.

M. Tech. Power System, Ist year, Semester I

	L	T	P	Credit
RESTRUCTURING IN POWER SYSTEMS	**3**	**1**	**0**	**04**

EEPS105

1. **Course Outcomes (COs):**

At the end of the course, the students will be able to:

CO1	The students would be able to understand the basics and benefits of restructuring and deregulations.
CO2	The students would be able to evaluate the market scenario and completion in deregulated environment.
CO3	The students would be able to understand the pricing and agreements associated with deregulation policies.
CO4	The contingency and ancillary service management will be explored for restructured and deregulated system.
CO5	The impact of availability and unavailability in terms of reliability indices will be explored for power system network.

2. **Syllabus**

- **Deregulation Of the Electricity Supply Industry** **06 hrs.**
  Deregulation, Reconfiguring Power systems, unbundling of electric utilities, Background to deregulation and the current situation around the world, benefits from a competitive electricity market, after-effects of deregulation.
- **Power System Operation in Competitive Environment** **11 hrs.**
  Role of the independent system operator, Operational planning activities of ISO: ISO in Pool markets, ISO in Bilateral markets, Operational planning activities of a GENCO: Genco in Pool and Bilateral markets, market participation issues, competitive bidding.
- **Transmission Open Access and Pricing Issues** **08 hrs.**
  Power wheeling, Transmission open access, pricing of power transactions, security management in deregulated environment, and congestion management in deregulation.
- **Ancillary Services Management** **08 hrs.**
  General description of some ancillary services, ancillary services management in various countries, reactive power management in some deregulated electricity markets.
- **Reliability and Deregulation** **12 hrs.**
  Reliability analysis: interruption criterion, stochastic components, component models, calculation methods, Network model: stochastic networks, series and parallel connections, minimum cut sets, reliability costs, Generation, transmission and distribution reliability, Reliability and deregulation: conflict, reliability analysis, effects on the actual reliability, regulation of the market.

Total Hours-45

Tutorials will be conducted separately for 15 hours

3. **Books Recommended:**

1 K. Bhattacharya, MHT Bollen and J.C Doolder, “Operation of Restructured Power Systems”, Kluwer Academic Publishers, USA, 2001.
2 Lei Lee Lai, “Power System restructuring and deregulation”, John Wiley and Sons, UK. 2001.
3 Fred I Denny and David E. Dismukes, “Power System Operations and Electricity Markets”, CRC Press, LLC, 2002.

M. Tech. Power System, Ist year, Semester I

DIGITAL SIGNAL PROCESSING

EEPS111 (Elective I)

L	T	P	Credit
3	0	0	03

1. **Course Outcomes (COs):**

At the end of the course, the students will be able to:

CO1	Classify the discrete time signals and systems and analyze the system stability.
CO2	Design optimum structures for realizing IIR and FIR systems.
CO3	Analyze the signals using frequency domain analysis.
CO4	Design and implement different types of FIR/IIR filters.
CO5	Apply signal processing techniques to real situation problems.

2. **Syllabus**

- **Discrete Time Signals and Systems** **13 hrs.**
  Classification Of Discrete Time Signals and Systems, Quantization Error, Stability Analysis, Correlation, Sampling Theorem, Aliasing, Z-Transforms And Its Application To The Analysis Of LTI Systems, Realization Of Discrete-Time Systems: Direct Form – I, II, Recursive And Non-Recursive Realization.
- **Discrete Time Fourier Transform** **14 hrs.**
  Definition and properties of DTFT and DFT and their inverses, efficient computation of DFT: FFT algorithms: DIT and DIF, Time-domain aliasing, Application of DFT in linear filtering: Overlap and save, Overlap and add methods
- **Digital Filters** **14 hrs.**
  Concept of filtering, phase and group delays, Design of IIR filters from analog filters (Butterworth and Chebyshev) by impulse invariance and bilinear transformation, Windowing techniques for FIR filter design, Selection of window function based on the specification.
- **Applications Of DSP** **04 hrs.**
  Applications of DSP to power electronics/ power system/ Instrumentation.

Total Hours-45

3. **Books Recommended:**

1 Sanjit Mitra, Digital Signal processing, McGraw-Hill Science/Engineering/Math; 3 edition, 2005.
2 Proakis-Manolakis, Digital signal Processing, 3rd edition, PHI, 2000.
3 Oppenheim-Schetor, Discrete time signal processing, 2nd edition, Prectice Hall, 1997.
4. Schaum’s outline: Digital Signal Processing, Monson H. Hayes, McGraw Hill.
5. Introduction to Digital Signal Processing by Jonny R. Johnson, Prentice Hall India Learning Private Limited.

M. Tech. Power System, Ist year, Semester I

POWER ELECTRONICS (Elective I)

EEPS113

L	T	P	Credit
3	0	0	03

1. **Course Outcomes (COs):**

At the end of the course, the students will be able to:

CO1	To understand the concept of Power semiconductor devices and also design magnetic components.
CO2	To Analyze various types of DC-DC converters.
CO3	To develop various PWM schemes for inverters.
CO4	To describe the operation of various line commutated converters.
CO5	To categorize various multi-level inverters & resonant converters.

2. **Syllabus**

- **Review of Power Semiconductor Devices** **08 hrs.**
  Review of Power semiconductor devices, Gate and Base drive circuits - Preliminary design considerations, Temperature control of power devices, Heat sink design, and Design of Magnetic components. Introduction to Wide Band gap semiconductor devices (SiC & GaN)
- **DC-DC Converters** **10 hrs.**
  Buck converter, Boost converter, Buck-Boost converters, CUK converter, Fly-back converter, Forward converter, Push-pull converter, Full bridge and Half bridge converters, Design considerations and comparison.
- **Inverters** **10 hrs.**
  Review of single-phase bridge inverters, 3-phase bridge inverters, Pulse width modulated inverters, 1-pulse and multi pulse modulation, Sinusoidal PWM, Space Vector PWM, Reduction of harmonics - Selective Harmonic Elimination Technique.
- **Line Commutated Converters** **10 hrs.**
  Principle of phase control, Review of single-phase converters, 3 phase half and fully controlled converters, 12-pulse converter, Dual converters.
- **Introduction to Multilevel and Resonant Converters** **07 hrs**.
  Principle and operation of Neutral Point clamped, Flying capacitor and Cascaded H-Bridge inverters. Principle and Operation of Load Resonant, ZCS and ZVS converters.

Total Hours-45

3. **Books Recommended:**

1 Rashid, M. H., "Power Electronics Handbook", Elsevier Academic Press, 2001.
2 Ned Mohan, Tore M. Undeland and William P. Robbins, “Power Electronics Converters, Applications, and Design”, John Willey & Sons, Inc., 2nd Edition, 1995.
3 Agrawal, J. P., "Power electronic systems: Theory and design" Addison Wesley Longman (Singapore) Pte. Ltd. New Delhi, 2001.
4. Rashid, M. H., "Introduction to PSpice Using OrCAD for Circuits and Electronics, Prentice-Hall of India Pvt. Ltd., New Delhi, Eastern Economy Edition, Third Edition 2006.
5. Joseph Vithayathil, "Power Electronics: Principles and Applications", Mcgraw-Hill, 1995.
6. Erickson Robert W., Maksimovic Dragan, "Fundamentals of Power Electronics", Kluwer Academic Publishers Group (Netherlands), 2001.
7. A. Pressman, “Switching Power Supply Design”, McGraw-Hill, 1998.

M. Tech. Power System, I^st year, Semester I

	L	T	P	Credit
DISTRIBUTED GENERATION (Elective I)	**3**	**0**	**0**	**03**

EEPS115

1. **Course Outcomes (COs):**

At the end of the course, the students will be able to:

CO1	Understand the necessity of Distributed Generation in distribution system.
CO2	Analyze micro-grids and investigate the different types of interfaces of DGs to microgrid.
CO3	Evaluate the impact of integration of Distributed Generation in protection scheme.
CO4	Appraise and evaluate the economic impact of DG integration in distribution system.
CO5	Evaluate various control aspects of DG in distribution system.

2. **Syllabus**

- **Distributed Generation** **14 hrs.**
  Gas turbine powered distributed generators, Electric vehicle as a Distributed generator (V2G, G2V), Fuel cell powered distributed generators, renewable resource distributed generators, Energy storage with distributed generators: Superconducting magnetic energy storage (SMES), capacitor storage, mechanical storage; Flywheels, pumped and compressed fluids, comparison of energy storage system, Hydrogen Technologies, Electric Vehicles
- **Micro Grid** **8 hrs.**
  Resources evaluation and needs, dimensioning integration systems, Optimizing integration systems, Integration systems control, Cases of study: multi-generation buildings
- **Planning & Operation of Distributed Generation** **11 hrs.**
  DG planning cost implications of power quality, cost of energy and net present value calculations and implications on power converter design, Power converter topologies and model and specifications for DG applications, Capacitor selection, choice of DC bus voltage, current ripple, capacitor aging and lifetime calculations. Voltage control techniques, reactive power control, Harmonics and power quality issues.
- **Protection in Distributed Generation** **12 hrs.**
  Introduction, over current protection, Distance protection, Differential protection, Protection coordination, Renewable energies protection, Distributed grid protection, Problems in distributed grids, Integration of mini and micro-generation in distribution grids, V2G integration, Islanding Schemes.

Total Hours-45

3. **Books Recommended:**

1 J.N.Twidell & A.D.Weir-Renewable Energy Sources, University press,Cambridge.
2 Sukhatme, S.P., Solar Energy -Principles of Thermal Collection and Storage, Tata McGraw-Hill, New Delhi.
3 Kreith, F., and Kreider, J.F., Principles of Solar Engineering, Mc-Graw-Hill Book Co.
4. S.L.Soo ,Direct Energy Conversion , Prentice Hall Publication
5. James Larminie, Andrew Dicks, Fuel Cell Systems, John Weily & Sons Ltd
6. J. F. Manwell, J. G. McGowan, A. L. Rogers, Wind Energy Explained John Weily & Sons Ltd
7. E.J. Womack, MHD power generation engineering aspects, Chapman and Hall Publication.
8. G.D. Rai, Non Conventional energy Sources, Khanna Publications, New Delhi.

M. Tech. Power System, Ist year, Semester I

POWER QUALITY (Elective I)

EEPS117

L	T	P	Credit
3	0	0	03

1. **Course Outcomes (COs):**

At the end of the course, the students will be able to:

CO1	Describe various power quality issues.
CO2	Identify different methods to solve the power quality problems.
CO3	Apply passive and active compensation methods for solving power quality problems.
CO4	Analyze various modes of unified power quality conditioner.
CO5	Design active power filters for various operating conditions.
CO6	Summarize the benefits of using the power quality improvement devices.

2. **Syllabus**

- **Introduction to Power Quality:** **05 hrs**
  Definition, Power Quality Problems, Causes and Consequences, voltage sags, swells, interruptions, flicker, reactive power and harmonics. Power quality indices, IEEE and IEC standards related to power quality.
- **Origin of power quality variations** **05 hrs**
  Voltage Frequency Variations, Voltage Magnitude Variations, Voltage Unbalance, Voltage Fluctuations and Light Flicker, Waveform Distortion
- **Origin of power quality events** **08 hrs**
  Interruptions: Terminology, Causes, Restoration and Voltage Recovery. Voltage Dips: Causes of Voltage Dips, Voltage-Dip Examples, Voltage Dips in Three Phases, Phase-Angle Jumps Associated with Voltage Dips, Voltage Recovery After a Fault. Transients: Lightning Transients, Normal and Abnormal switching transients
- **Shunt and Series compensation** **15 hrs**
  Passive shunt compensation, Active load compensation, D-STATCOM - Design, Control and Phasor Analysis.
  Dynamics of sags and swells, Passive Series Compensation, Active Series Compensation- Dynamic Voltage Restorer (DVR) with and without energy support- Design, Control and Phasor Analysis.
- **Unified Power Quality Conditioner (UPQC)** **04 hrs**
  Right Shunt and Left Shunt Topologies, Phasor Analysis of UPQC-P, Q and S under various perturbations.
- **Active power filters** **08 hrs**
  Voltage and Current Harmonics- Causes and Consequences. Design of Passive Filters. Active Shunt Filters and Active Series Filters, Hybrid Filters, Improved Power Quality Converters.

Total Hours-45

3. **Books Recommended:**

1 Bollen Math H.J. ,GUIrene Y.H., “Signal Processing of Power Quality Disturbances”, Wilely Inter science Publication (IEEE Press),2006.

2 Bhim Singh, Ambrish Chandra, and Kamal Al-Haddad, Power Quality: Problems and Mitigation Techniques, John Wiley and Sons, United Kingdom, Dec. 2014
3 Arindam Ghosh and Gerard Ledwich, Power Quality Enhancement using Custom Power Devices, Springer Science and Business Media, New York, Dec. 2012.
4 Wakileh George J.“Power System Harmonics: Fundamentals, analysis and filter Design,” Springer,(first Indian reprint) 2007.
5 Hirofumi Akagi, Edson Hirokazu Watanabe and Mauricio Aredes, Instantaneous Power Theory and Applications to Power Conditioning, John Wiley and Sons, New Jersey, March, 2007

M. Tech. Power System, Ist year, Semester I	**L**	**T**	**P**	**Credit**
MICROCONTROLLER BASED SYSTEM DESIGN (Elective I)	**3**	**0**	**0**	**03**
EEPS119				

1. **Course Outcomes (COs):**

At the end of the course, the students will be able to:

CO1	Revise basic concepts of 8051 microcontrollers and embedded 'C' programming.
CO2	Explain architecture of CIP 51 8-bit microcontroller with the advanced features of the controller.
CO3	Describe the functionality of Programmable internal and external peripherals of CIP 51.
CO4	Write embedded 'C' code for CIP51 with the exposure of SI Lab IDE.
CO5	Develop microcontroller-based prototype for automation, power electronics based electrical systems and other real-world problems.

2. **Syllabus**

- **Review of 8051 Architecture & Embedded 'C' Programming** **07 hrs.**
  Introduction, 8051 family microcontrollers, hardware architecture, input/output pins, I/O ports and circuits, general purpose registers, special function registers, timers-counters, concepts of interrupts. Variables and constants, storage classes, enumerations and definitions, I/O operations, control statements, functions, pointers and arrays, structure and unions, interrupt service routines.
- **Introduction To Cip-51 Controller Architecture** **10 hrs.**
  Memory Map, Instruction Pipeline, PLL & Clock System, concept of Crossbar and Pin assignment, On Chip Peripherals: Timer/Counters, GPIO, ADC, DAC, UART.
- **Hardware Concepts and Programming of Cip-51 Peripherals** **14 hrs.**
  Comparator, SPI & I2C serial Communication interface, MAC unit on CIP-51, Programming of PCA, ADC, DAC. Interfacing of seven-segment LED, LCD display, relay, Pushbutton keys, Matrix key board and Stepper motor.
- **Applications** **14 hrs.**
  Design of digital Multimeter, numerical relay, control of DC – DC Converters, DC-AC inverters.

Total Hours-45

3. **Books Recommended:**

1 Muhammad Ali Mazidi, Rolin McKinlay and Janice Gillispie Mazidi "The 8051 Microcontroller and Embedded Systems: Using Assembly and C" Pearson 2nd edition, 2007.
2 M. Mazidi, J. G. Mazidi and R. D. McKinlay, The 8051 Microcontroller and Embedded Systems, Prentice Hall of India, 3rd edition, 2007.
3 Mark Siegesmund, Embedded C Programming: Techniques and Applications of C and PIC MCUS, Elsevier Science, 1 st Edition 2014.
4. Chew Moi, Gourab Sen Gupta "Embedded Programming" Silicon Labs 8-bit MCUniversity Program.
5. Datasheet of SILABS C8051FXXX. (www.silabs.com)
6. Application notes from SILAB C8051FXXX.

M. Tech. Power System, Ist year, Semester I	**L**	**T**	**P**	**Credit**
POWER SYSTEM TRANSIENTS (Elective I)	**3**	**0**	**0**	**03**
EEPS131				

1. **Course Outcomes (COs):**

At the end of the course, the students will be able to:

CO1	To study Generation of switching transients and their control
CO2	To distinguish between various switching transients and lightning surges.
CO3	To observe the behavior of travelling waves such as the propagation, reflection and refraction of travelling waves.
CO4	To study the effect of voltage transients caused by faults, circuit breaker action, load rejection on integrated power system.
CO5	Determine the skill to design the protection scheme of power system equipment using ground wires, surge absorbers and arrestors.

2. **Syllabus**

- **Over voltages in Power Systems** **12 hrs.**
  Transient over voltages due to lightning, Theory of ground wires, Direct stroke to a tower, Effect of reflection up and down the tower, Tower grounding and counterpoises, Switching transients, Single and double frequency transients, Abnormal switching transients, Capacitance switching, Kilometric fault, Line dropping and load ejection, Closing and reclosing of lines, High charging currents, Over voltages induced by faults, Ferro-resonance, Switching transients in integrated systems, Peaking switching over voltages in EHV lines and cables.
- **Travelling Waves in Transmission Lines** **13 hrs.**
  Origin and nature of power system transients, Traveling waves on transmission lines, General wave equation, Attenuation and distortion of waves, Reflection and refraction of traveling waves at different line terminations, Bewley Lattice Diagram, Traveling waves in multi-conductor systems, Transition points on multiconductor circuits.
- **Protection Against Travelling Waves** **08 hrs.**
  Rod gap, Arcing Horn, Lightning Arresters, Surge Absorber, Insulation Coordination
- **Transient In Transformers and Rotating Electrical Machines** **12 hrs.**
  High frequency transients and voltage distribution in windings of transformer and rotating electrical machines, Surge impedance

Total Hours-45

3. **Books Recommended:**

1 I.V. Begley, 'Traveling waves in Transmission Systems', John Wiley (1933,51), Dover.
2 R. Rudenberg. 'Electric Stroke waves in Power Systems', Harvard University Press, Cambridge, Massachusetts.
3 Allan Greenwood, 'Electric Transients in Power Systems', Wiley Interscience.
4. C.S. Indulkar and D.P. Kothari, 'Power System Transients, A Statistical Approach', Prentice-Hall of India Pvt. Ltd., New Delhi. 110 001.
5. V.A. Venikov,'Transient phenomena in Electrical Power Systems', Pergamon Press, London.

M. Tech. Power System, Ist year, Semester I

FORECASTING AND PLANNING METHODS (Elective II)

L	T	P	Credit
3	0	0	03

EEPS133

1. **Course Outcomes (COs):**

At the end of the course, the students will be able to:

CO1	The students would be able to understand the basics of forecasting and planning for engineering.
CO2	The students would be able to learn methods of time series decomposition and its smoothing for better forecasting and planning.
CO3	The students would be able to learn various simple and multiple regression models for forecasting.
CO4	The students would learn the BOX-Jenkins and ARIMA for forecasting
CO5	The students would be able to learn the basics of planning for engineering applications.
CO6	The students would be able to learn various methods of planning and their applications.

2. **Syllabus**

- **Fundamentals of Forecasting** **04 hrs.**
  The forecasting perspective, Current Status Of Forecasting, Fundamentals Of Quantitative Forecasting, Explanatory And Time Series Forecasting, overview of forecasting techniques and basic steps, basic forecasting tools, time series, and cross-sectional data, time plots, time series patterns, seasonal plots, scatterplots, univariate and bivariate statistics, autocorrelation, measuring forecast accuracy, standard accuracy, out-of-sample accuracy, ACF of forecast error, prediction intervals, least square estimates, transformation and adjustments.
- **Time-series decomposition and Exponential smoothing methods** **08 hrs.**
  Principle of decomposition, model, graphics, seasonal adjustment, moving averages, simple, centred, double moving and weighted moving averages, local regression smoothing, classical decomposition, additive and multiplicative decomposition, variations on classical decomposition, census bureau methods, first iterations, later iterations, extensions to X-12 ARIMA, STL decomposition, comparing STL with X-12 ARIMA, Exponential smoothing methods: The forecasting scenario, averaging methods, the mean, moving averages, exponential smoothing methods, single exponential smoothing and its adaptive approach, Holt's linear method, Holt-Winter's trend and seasonality method, exponential smoothing: Pegel's classification, general aspects of smoothing methods
- **Simple and multiple Regression** **08 hrs.**
  Simple regression: Regression methods, simple regression, least squares estimation, the correlation coefficient, residuals, outliers and influential observations, inference and forecasting with simple regression, regression as statistical modelling, The F-test for overall significance, confidence intervals for individual coefficients, t-tests for individual coefficients, forecasting using the simple regression model, non-linear relationship, non-linearity in the parameters, using logarithms to form linear models, local regression Multiple Regression: Introduction, theory and practice, solving for the regression coefficients, multiple regression and coefficient of determination, The F-test for overall significance, individual coefficients, t-tests for individual coefficients, regression with time series, selecting variables, multicolinearity, forecasting using the multiple regression model.
- **The BOX-JENKINS methodology for ARIMA models** **06 hrs.**
  Examining correlation in time series data, the autocorrelation function, white noise model, sampling distribution of autocorrelation, the partial autocorrelation coefficient, recognizing seasonality,

examining stationarity of time series data, random walk model, tests for stationarity, seasonal differencing, backshift notion, ARIMA models of time series, autoregressive model of order one, moveing average model of order one, higher order models, Mixtures ARIMA models, identification and estimation of parameters, forecasting with ARIMA.

- **Forecasting And Planning** **10 hrs**.

  The role of forecasting in planning, Comparison and selection of forecasting methods, the accuracy of forecasting methods, Pattern of the Data and its effects on individual forecasting methods, Time horizon effects on forecasting methods.

  Introduction to Planning: Defining planning as a discipline, multidisciplinary nature, role of a planner, fields of planning- Urban, regional, environmental, Electrical Infrastructure planning definitions and Basics of Planning, Goals and objectives of planning; Components of planning; Benefits of planning; Arguments for and against planning. Planning Process, Levels of Planning in India.

- **Planning Methods** **09 hrs.**

  Definition of development plan; Types: Master plan, Structure plan, District plan, Action area plan, Subject plan, Comprehensive planning, Zonal plans etc. Hierarchy of plans: Regional plan, Sub-regional plan; Sector plans and Spatial plans, Data requirements for planning; sources of primary and secondary data; questionnaire design, measurement scale and their application, sampling techniques, types of socio-economic surveys; self-surveys, interviews, questionnaires and observer participation, Data requirement for various types of regional plans; Techniques for conducting surveys.

Total Hours-45

3. <u>Books Recommended:</u>

1 Makridakis, Spyros, “Forecasting methods and application”, John Wiley, 1993.
2 X.Wang & J.R. Mc Donald, “Modern Power system planning”, McGraw. Hill, 1993
3 A.S Pabla , “Electrical Power system planning”, Mac Millan,Delhi,1998
4. Sullivan, “Power system planning”, McGraw. Hill, 1977
5. Lakervi E, E J Holmes, “Electricity distribution network design”, IEE, 2nd edition, 2003
6. A Reader in Planning Theory, Faludi, A., Pergamon Press, Oxford.
7. Planning Theory, Faludi, A., Pergamon Press, Oxford.
8. Regional Planning: Concepts, R.P. Mishra, 1992 Concept Publishing Techniques Policies
9. Planning Theory and Philosophy, Cambia, M., Taylor and Francis. Philosophy

M. Tech. Power System, Ist year, Semester I
OPERATION AND ANALYSIS OF DISTRIBUTION SYSTEM (Elective II)

L	T	P	Credit
3	0	0	03

EEPS135

1. **Course Outcomes (COs):**

At the end of the course, the students will be able to:

CO1	Recognize configuration of distribution feeder and understand load behaviour.
CO2	Determine voltage drop and power loss and develop system component models.
CO3	Analyze different methods of power flow and execute short circuit studies.
CO4	Perform voltage control analysis of electrical distribution systems.
CO5	Apply state estimation methods for distribution system.
CO6	Explain basic concept and identify appropriate protection scheme for distribution system.

2. **Syllabus**

- **Introduction to Distribution Systems** **04 hrs.**
  Structure of distribution system, distribution feeder configuration and substation layouts, construction and bus schemes, substation location and rating, overhead and underground distribution networks
- **Load Characteristic and Load Modelling, System Component Modeling** **07 hrs.**
  Definitions, Loads and Load Characteristics, loss factor, Load Growth and Diversified Demands, Load Models, feeder load; Overhead lines, feeders and cables, Single and three phase transformers, voltage regulators, capacitor banks, three phase induction machines, distributed generation.
- **Distribution System Analysis** **10 hrs.**
  Load flow analysis: Backward/forward sweep, Direct approach, Direct approach for weakly meshed systems, Gauss Implicit Z-matrix Method; Fault Studies: general short circuit theory, specific short circuits, backfeed ground fault currents, weakly meshed systems; case study.
- **Voltage Regulation in Distribution Systems** **04 hrs.**
  Basic Definitions, Quality of Service and Voltage Standards, Voltage Control, Feeder Voltage Regulators, LineDrop Compensation, Distribution Capacitor Automation, Voltage Fluctuations
- **State Estimations of Distribution System** **05 hrs.**
  Topology estimation, pseudo measurements, state estimation for radial distribution system, state estimation scheme, object-oriented state estimation, measurement placement, case study
- **Reliability Assessment of Distribution Systems** **04 hrs.**
  Introduction, reliability modelling concept, different reliability indices, customer interruption cost evolution and customer damage function
- **Distribution System Planning and Automation** **06 hrs.**
  Introduction, different components of distribution system planning, different planning approaches, planning models and solution strategies; introduction to distribution system automation, the basic elements of distribution system automation, power market deregulation and distribution system automation, load management at different peak and off-peak duration, compatibility of load management with system design and operation, smart grid and smart metering
- **Distribution System Protection** **05 hrs.**
  Basic Definitions, objective of distribution system protection, overcurrent protection devices, coordination of protective devices, high impedance faults, lightning protection, insulators.

Total Hours- 45

3. **Books Recommended:**

1 Turan Gonen, "Electric power distribution engineering", CRC press, 2015
2 W. H. Kersting, "Distribution system modelling and analysis", CRC press, 3rd edition, 2012
3 A.S Pabla, "Electrical Power system planning", Mac Millan,Delhi,1998
4. V. Kamaraju, "Electrical power distribution systems", Tata McGraw Hill, 2009
5. H. Lee Willis, "Power Distribution Planning Reference Book", CRC Press, 1st edition, 2004

M. Tech. Power System, I[st] year, Semester I

L	T	P	Credit
3	0	0	03

ELECTRICAL MACHINES FOR RENEWABLE ENERGY GENERATION (Elective II)

EEPS137

1. **Course Outcomes (COs):**

At the end of the course, the students will be able to:

CO1	Explain the fundamental issues and challenges of harvesting Renewable energy.
CO2	Analyze the different forms of energy storage by renewable energy sources.
CO3	Explain principle and construction, characteristics of electrical machines promising for renewable energy.
CO4	Compare existing machines and advanced renewable energy machines.
CO5	Identify the design modification of machines for renewable energy.
CO6	Select the appropriate electrical machines for harnessing renewable energy.

2. **Syllabus**

- **Forms of Energy Storage by Renewable Energy Sources** **02 hrs.**
  Kinetic energy, Potential Energy, Heat energy.
- **Classification of Electric Machines** **05 hrs.**
  Different of topologies of electric machines, Existing machines and Advanced machines for renewable energy
- **Existing Machines for Renewable Energy** **18 hrs.**
  Classifications Principle, construction and characteristics of Synchronous Generator, Induction Generator, Doubly Fed Induction Generator, Permanent Magnet Synchronous Generator, Linear Permanent Magnet Synchronous Generator.
- **Advanced Renewable Energy Machines** **20 hrs.**
  Classifications, Principle, construction characteristics and Application of Stator-PM Machines.
  Direct-drive PM Machines and Magnet less Machines

Total Hours-45

3. **Books Recommended:**

1 K.T. Chau. Electric Machines and Drives for Renewable Energy Harvesting, Energies, special issues, MDPI, 2017.
2 D.P. Kotahri, K.C. Singal, Rakesh RanjanRenewable Energy sources and emerging technologies, PHI, 2009
3 Pyrhonen, J.; Jokinen, T.; Hrabovcova, V. Design of Rotating Electrical Machines; Wiley: Chichester, UK, 2007.
4. D.S. Chauhan, S. K. Srivatava, Non- Conventional Energy Resources, New Age international Publishers, Third edition,2014.
5. Selected Journal papers on Advanced Electrical machines for Renewable Energy.

M. Tech. Power System, Ist year, Semester I

SYSTEM THEORY (Elective II)

EEPS139

L	T	P	Credit
3	**0**	**0**	**03**

1. Course Outcomes (COs):

At the end of the course, the students will be able to:

CO1	Understand the concepts of vector spaces and subspaces.
CO2	Explain the concepts of linear algebra and its application to control theory.
CO3	Analyze discrete time systems with z-transforms.
CO4	Evaluate the stability of discrete time systems and obtain the state space representation of discrete time systems.
CO5	Design controllers and observers for discrete time systems.

2. Syllabus

- **Linear Algebra** **21 hrs.**
  Vector spaces, Basis, Operator, range of the linear operator, null space, rank, nullity, rank-nullity theorem, matrix representation of the linear operator in the bases, orthogonal bases, Inner product spaces, Holder inequality, Cauchy-Schwartz inequality, triangular inequality, Minkowski inequality, best approximation theorem , orthogonal projection lemma, Gram- Schmidtt orthogonalization, Characteristics polynomial, minimal polynomial, eigen value and eigen vector, Diagonal form, Triangular form, Caley- Hamilton Theorem.
- **System Theory** **24 hrs.**
  Introduction to Z transformation, bilateral and unilateral Z transformation, Z transformation of the important signals, Solving Discrete LTI system using Z transformation, Pulse transfer function, Phase space analysis of the discrete LTI system, Jury Stability criterion , Schur-Cohn test, Bilinear transformation applied with Routh's stability criterion. Conservative system, Controllability, Obsrvability, Observer Design, Diaphantile equation, Full order, reduced order, minimum order observer, Gopinath Observer, Luenberger Observer.

Total Hours-45

3. Books Recommended:

1 Kenneth Hoffmann And Ray Kunze, "Linear Algebra", PHI India limited, 1971.

2 K. Ogata, "Discrete-Time Control Systems", Prentice Hall; 2nd edition, 1995.

3 Allen V. Oppenheim, S. Willsky, with S. Hamid Navab ''Signals and systems" Prentice Hall; 2nd edition, 1996.

4. K. Ogata, "Modern Control Engineering", 3rd Edition, PHI India limited, 2001.

5. I. J. Nagrath and M. Gopal, "Control System Engineering", Anshan Publishers; 5th edition, 2008.

Energy Audit

M. Tech. (Electrical) (Power Systems) **Energy Audit** **EEPS91**	**Scheme**	**L**	**T**	**P**	**Credit**
		0	**0**	**10**	**5**

Course outcomes:

At the end of this course the students will be able to

CO1	Explain the energy audit process and its importance
CO2	Understand various standards related to energy audit
CO3	Assess the data collected from various sources for energy audit
CO4	Prepare the energy audit report
CO5	Perform case studies for different types of establishments

Sl. No.		**Hours**
1.	Introduction to Energy Audit: Global standards of Energy Audit, Direct and indirect benefits of energy audit, Energy Audit Process	25
2.	Types of Energy Audit: Preliminary and Detailed Audit, Visible Energy loss identification in walk through audit, Energy Audit criteria, Scope of energy Audit, Selection of Audit team Energy Audit Plan	25
3.	Preparation of Energy Audit: Collecting energy bills and data, Conducting preliminary analysis, Sample Energy flow charts	25
4.	Execution of Energy Audit: Data inventory and management, Graphical representation of data, Analysing Energy use pattern, Bench-marking and comparative analysis, Identifying Energy Saving Potential Cost benefit analysis	25
5.	Reporting of Energy Audit: Preparing Energy Audit Report with Recommendations, Preparing Action Plan, Implementing the action plan, Sample audit report	25
6.	ISO 50001 and Energy Management Case Studies: ISO 50001, Features of ISO 50001	25
7.	Case Studies of various types of buildings or industries etc.	50
	Total (Notional Hours)	200

Second Semester

M. Tech. Power System, I^st year, Semester II

POWER SYSTEM DYNAMICS AND CONTROL (Core-IV)

EEPS102

L	T	P	Credit
3	1	2	05

1. **Course Outcomes (COs):**

   At the end of the course, the students will be able to:

CO1	Describe the fundamental concept of stability and the characteristics of Power system dynamics when subjected to different stresses
CO2	Develop dynamic modelling of power system components for stability studies
CO3	Investigate stability issues of single and multi-machines systems in power systems
CO4	Design the controllers to enhance the small signal stability of the power system
CO5	Interpret different schemes for improving transient stability and voltage stability.

2. **Syllabus**

- **Basic Concepts** **04 hrs.**
  Power system stability states of operation and system security, system dynamics problems, system model, analysis of steady State stability and transient stability, simplified representation of Excitation control.
- **Modeling of Synchronous Machine** **06 hrs.**
  synchronous machine, park's Transformation, Analysis of steady state performance, Equivalent Circuits of Synchronous machine, Determination of parameters of equivalent circuit, Transient Analysis of a Synchronous Machine.
- **Excitation System** **03 hrs.**
  Excitation System Modeling, Standard Block Diagram, System Representation by State Equations
- **Dynamics of a Synchronous Generator Connected To Infinite Bus** **06 hrs.**
  System Model, Synchronous Machine Model, Application of Model 1.1, Calculation of initial Conditions, System Simulation, Inclusion of SVC Model.
- **Analysis of Single Machine System** **04 hrs.**
  Small Signal Analysis, Application of Routh-Hurwitz Criterion, Small Signal Model
- **Application of Power System Stabilizers** **05 hrs.**
  Basic Concepts of PSS, Control Signals, Structure and tuning of PSS, Field Implementation, PSS Design and Applications, Resent Development and Future Trends
- **Multi Machine System** **07 hrs.**
  Simplified model, Improved model of the system for linear load, Inclusion of dynamics of load and SVC, introduction to analysis of large power system.
- **Transient And Voltage Stability** **10 hrs.**
  Definition, Equal area criteria, Numerical integration methods, Transient stability analysis, factors affecting voltage instability and collapse, analysis and comparison of angle and voltage stability, analysis and comparison voltage instability and collapse, control of voltage instability, Implication on power system dynamic performance.

Total Hours-45

Note: Tutorials will be conducted separately for 15 hours

3. Books Recommended:

1 K.R.Padiyar ,“Powerm System Dynamics Stability and Control”, Second Edition, B S Publication, 2008.

2 Prabha Kundur, “Power System Stability and, Tata McGraw Hill pub, 2006.

3 P.M.Anderson, A.A. Fouad,”Power System Control and Stability”, Second Edition, John Wiley and 2002.

4. List of Experiments

1 To study mathematical modeling of R-L-C and complex electrical circuits using MATLAB. 2.

2 To find the eigen values and eigen vectors of R-L-C circuits using state space analysis

3 To obtain the free response of a given system and understand the concepts of modes

4 . To observe variation of rotor angle and to find critical clearing time when fault occurs at:

(1) Sending end of the line

(2) Mid-point of the line

(3) When the fault at mid-point is cleared by removing the faulty line of SMIB system

5 To solve the swing equation by applying numerical method.

6 To simulate the SMIB system with different loading conditions using model 1.1 in MATLAB.

7 To design PSS using classical method for SMIB system.

8 To simulate Two area (4 machine, 10 bus) multimachine system using model.1.

M. Tech. Power System, Ist year, Semester II

APPLICATIONS OF POWER ELECTRONICS IN POWER SYSTEMS (Core-V)

EEPS104

L	T	P	Credit
3	1	2	05

1. **Course Outcomes (COs):**

At the end of the course, the students will be able to:

CO1	To evaluate compensator requirement for voltage regulation and load compensation.
CO2	To understand transmission line problems and their mitigation
CO3	To evaluate the effect of shunt controllers on operation of transmission line
CO4	To evaluate the effect of series controllers on operation of transmission line
CO5	To evaluate the effect of shunt-series controllers on operation of transmission line
CO6	To evaluate effectiveness of DVR.

2. **Syllabus**

- **Theory of Load Compensation** **05 hrs.**
  Requirement and objectives of load compensation, specification of load compensator, voltage regulation, shunt active filter for harmonics and reactive power compensation, relationship between variables in abc, alpha-beta and dq domain.
- **AC Transmission line and Reactive Power Compensation** **12 hrs.**
  Fundamentals of ac power transmission, transmission problems and needs, analysis of uncompensated AC line, Passive reactive power compensation, comparison between series and shunt capacitor compensation, Compensation by STATCOM and SSSC, Generalized equivalent circuit for FACTS controller with their control variables and constraint equations.
- **FACTS Controllers for Shunt Compensation** **11 hrs.**
  Variable Impedance type (SVC) & switching converter type (STATCOM) shunt controllers, their theory, configuration, characteristics, control and applications. Simulations of these controllers in PSCAD/MATLAB.
- **FACTS Controllers for Series Compensation** **12 hrs.**
  Variable Impedance type (TCSC) & switching converter type (SSSC) series controllers, their theory, configuration, characteristics, control and applications. Simulations of these controllers in PSCAD/MATLAB.
- **Unified Power Flow Controller (UPFC)** **07 hrs.**
  Theory, configuration, characteristics, control and applications of UPFC. Simulations of UPFC controllers in PSCAD/MATLAB.
- **Dynamic Voltage Restorer (DVR) and Unified Power Quality Conditioner (UPQC)** **07 hrs.**
  Theory, configuration, characteristics, control and applications of DVR and UPQC. Simulations of these controllers in PSCAD/MATLAB.

Total Hours-45

Note: Tutorials will be conducted separately for 15 hours

3. Books Recommended:

1. K.R.Padiyar ,"Powerm System Dynamics Stability and Control", Second Edition, B S Publication, 2008. FACTS controllers for transmission and Distribution system by K. R. Padiyar New Age international Publishers 1st edition -2007.
2. Understanding FACTS: Concepts and Technology of Flexible AC Transmission by N. G. Hingorani and Laszlo Gyugyi, IEEE Press, New York, 2000.
3. P.M. Reactive Power Control in Electric Systems by T. J. E. Miller, John Wiley & Sons, 1982
4. Flexible ac transmission systems (FACTS) by Song, Y.H. and Allan T. Johns, Institution of Electrical Engineers Press, London, 1999.
5. Thyristor based FACTS controllers for electrical transmission systems by Mathur R. M. and Verma R. K, IEEE press series on power engineering Wiley IEEE press, 2002.

4. List of Experiments

1 To verify calculation of load balancing in MATLAB simulink.

2 Verification of long line performance equations using MATLAB simulink.

3 Implementation of various PWM methods: SPWM, Selective harmonic elimination, space vector in simulink.

4 To verify relationship of variables in various domain such abc, alpha-beta and d-q.

5 Simulation of active filter for linear and non-linear loads.

6 Simulation of TCR and verify harmonic profile in both single phase and three phase system.

7 Simulation of TCSC for various modes.

8 Simulation of STATCOM.

9 Simulation of SSSC.

10 Simulation of UPFC.

M. Tech. Power System, Ist year, Semester II

HIGH VOLTAGE ENGINEERING & EHV AC TRANSMISSION (Elective III)

EEPS112

L	T	P	Credit
3	0	0	03

1. **Course Outcomes (COs):**

At the end of the course, the students will be able to:

CO1	To generate and measure High Voltage AC & DC, Impulse voltage & current.
CO2	To perform Non-destructive testing of insulation.
CO3	To design high voltage laboratory.
CO4	To determine line parameters, voltage gradient, corona loss, Radio noise, Electrostatic field of EHV AC transmission line.
CO5	To analyse voltage gradient, corona effects, Electrostatic field of EHV AC transmission line.

2. **Syllabus**

- **Generation of High Voltages** **08 hrs.**
  Generation of High DC Voltages: Half Wave and full wave circuits –Ripple voltages in HW and FW rectifiers. Simple and cascade voltage doubler. Crockroft Walton voltage multiplier circuits. Ripple and regulation. Electrostatic machines – principles – Van de Graff generator. Generation of high AC voltages: Cascade transformers, resonant transformers – parallel and series resonant test systems. Generation of high frequency high voltages – Tesla coil. Generation of impulse voltages – Standard impulse wave shape Basic circuits for producing impulse waves – Analysis of commercial impulse generator circuits – Wave shape control, multi-stage impulse generators – Marx circuit – modified Marx impulse generator circuit – Components of multi stage impulse generator. Generation of Switching surges. Generation of impulse current. Definition of impulse current waveform – Circuit for producing impulse current waves.
- **Measurements Of High Voltages & Currents** **05 hrs.**
  Measurement of high voltages and currents-DC, AC and impulse voltages and currents-DSO, electrostatic and peak voltmeters, sphere gaps-factors affecting measurements, potential dividers (capacitive and resistive)- series impedance ammeters, rogowski coils, hall effect generators.
- **Non-Destructive Testing of Insulation** **07 hrs.**
  Measurement of insulation resistance, polarization index, dielectric constant and loss factor. Partial Discharge Measurement, RI Measurement. HV Testing of various power apparatus, Condition monitoring of Electrical apparatus.
- **Design, Planning and Layout of HV Laboratory** **02 hrs.**
  Test Facilities, Activities & Studies in HV lab, Classification of hv lab, Size & rating of hv lab, grounding of impulse testing laboratories.
- **Introduction To EHV AC Transmission** **02 hrs.**
  Role of EHV AC transmission, standard transmission voltages, Average values of line parameters, power handling capacity and Line loss, surge impedance loading.
- **Calculation of Line and Ground Parameters** **06 hrs.**
  Resistance of conductors, Properties of bundle conductors, Inductance of EHV line configuration, Line capacitance calculation, Sequence inductance and capacitance, line parameters for Modes of propagation.

- **Voltage Gradients of Conductors** **06 hrs.**
  Field of sphere gap & line charges and their properties, charge potential relations for multi conductor lines, surface voltage gradient on conductors, gradient factors and their use, distribution of voltage gradient on sub conductors of bundle.
- **Corona And its Effects** **06 hrs.**
  Corona loss formulas, charge- voltage diagram and corona loss, Audible noise, limits for audible noise, AN measurement and meters, formula for audible noise and use in design, radio interference, limits of radio interference fields, CIGRE formula, measurement of RI, RIV and excitation function.
- **Electro Static Fields** **03 hrs.**
  Calculation of Electrostatic Field of AC Lines, Effect of High E.S. Field on Humans, Animals, and Plants.

Total Hours-45

3. <u>Books Recommended:</u>

1. M.S.Naidu, V. Kamaraju, "High voltage Engineering", TMH, 4th edition, 2008.
2. Begamudre, "EHV AC Transmission engineering", Wiley Easter Ltd. 4th Ed, 2011.
3. E,Kuffel, W.S.Zaengl, J.Kuffel, " High voltage Engineering Fundamentals" , Newnes, 2nd edition, 2000.
4. EPRI, Palo Alto, "Transmission line reference book 345 KV & above".

M. Tech. Power System, Ist year, Semester II

ELECTRIC VEHICLES TECHNOLOGY (Elective III)

L	T	P	Credit
3	0	0	03

EEPS114

1. Course Outcomes (COs):

At the end of the course, the students will be able to:

CO1	Understand the basic concepts of electric vehicles and popular traction systems.
CO2	Analyze the different propulsion unit and their working.
CO3	Understand the drive-train topologies and advanced propulsion techniques.
CO4	Analyze the various energy storage methodologies in traction systems.
CO5	Understanding the Energy Management in Electric Vehicle.

2. Syllabus

- **Conventional Vehicles** **09 hrs**
  Vehicle dynamics, Basics of vehicle performance, vehicle power source characterization, transmission characteristics and mathematical models to describe vehicle performance. Introduction to Hybrid Electric Vehicles: History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drivetrains on energy supplies.
- **Hybrid Electric Drivetrains** **09 hrs.**
  Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis. Electric Drive-trains; Basic concept of electric traction, introduction to various electric drive-train topologies. Power flow control in electric drive-train topologies, efficiency analysis.
- **Electric Propulsion Unit** **09 hrs.**
  Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Induction Motor drives, Permanent Magnet Motor drives, Switch Reluctance Motor drives, drive system efficiency
- **Energy Storage** **09 hrs.**
  Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based, Fuel Cell based, Super Capacitor based energy storage and its analysis, Hybridization of different energy storage devices. Sizing the drive system: Matching the electric machine and the internal combustion engine (ICE) Sizing the propulsion motor, sizing the power electronics selecting the energy storage technology, Communications, supporting subsystems
- **Energy Management Issues** **09 hrs.**
  Classification and comparisons of different energy management strategies, implementation implementation issues of energy management strategies, Case Studies: Design of a Hybrid Electric Vehicle (HEY), Design of a Battery Electric Vehicle (BEV).

Total Hours-45

3. Books Recommended:

1. Ali Emadi, Advanced Electric Drive Vehicles, CRC Press, 2014.
2. Iqbal Hussein Electric and Hybrid Vehicles: Design Fundamentals, CRC Pres, 2003.
3. Mehrdad Ehsani, Yi.mi Gao Sebastjan E. Gay, Ali Emadi, Modem Electric, Hybrid Electric and Fuel Cell Vehicles; Fundamentals Theory and Design, CRC Press 2004.
4 James Larminie John Lowry, Electric Vehicle Technology Explained , Wiley, 2003.

5 S. Onorio, L. Serrao and G. Rizzoni, 'Hybrid Electric Vehicles: Energy Management Strategies", Springer 2015.
6 T. Denton 'Electric a.ad Hybrid Vehicles' , Routledge 2016.

M. Tech. Power System, Ist year, Semester II

CRYPTOGRAPHY AND CYBER SECURITY (Elective III)

L	T	P	Credit
3	0	0	03

EEPS116

1. **Course Outcomes (Cos):**

At the end of the course, the students will be able to:

CO1	The students would be able to understand the concept of encryption and privacy issues and its significance in cyber security.
CO2	The students would be able to learn about cryptography and risk analysis using various terms and methods such as attack classification, ciphers, keys etc.
CO3	The students would able to learn the impact of bad data injection and identification for cyber security using encryption methods.
CO4	The students would be able to learn the use of cloud network for information storage for smart grids and its security. The Indian perspective will also be explored.
CO5	The privacy prevention and its methods would be learned for smart grids.
CO6	The students would be able to understand the management and legal concerns and rules/protocols for cyber security.

2. **Syllabus**

- **Introduction and Overview of the Security and Privacy Issues in electrical network** **04 hrs.**
  Security issues in smart grids, Physical network security, Information network security, Privacy issues in smart grids, Reliability in smart grid- preliminaries on reliability quantification, System adequacy quantification, Congestion prevention: An economic dispatch algorithm.
- **Cryptography for Cyber security** **08 hrs**.
  Introduction and Overview of Cryptography and security, Historical perspective, Threats, risks, consequences, Physical network security, Information network security, Sources of threats, Attacks classification, Preventive measures, remedial measures, Basics of cryptography: Confusion vs. diffusion, Stream ciphers vs. block ciphers, Keys and key management, Key exchange, Symmetric key cryptography vs asymmetric key cryptography, Cryptographic hash functions, Properties, Merkle Damgard construction, md family, sha family, Digital signatures , Public key encryption and Misc. techniques, Introduction, Public key crypto systems, RSA algorithm, Encryption using non-cryptographic tools, Authentication principles and methods, Passwords, two-factor authentication, One-way encryption
- **Bad Data Detection** **07 hrs.**
  Preliminaries on falsification detection algorithms, Autocorrelation function (ACF), Time series modeling of load power: Outline of the proposed methodology, Seasonality, Fitting the AR and MA models, Case study: Stabilizing the variance, Fitting the stationary signal, Model fine-tuning and evaluation.
- **Cloud Network Data Security in Smart Grid** **10 hrs.**
  Introduction, Service-level agreements, Live migration of a VM image in cloud computing: Data Migration, Network migration, Architecture and Solutions for: Application Manager, Site Broker, Hybrid cloud broker, Smart Meters and Smart Loads: The Advance Metering Infrastructure (AMI), AMI communication network, Hierarchical AMI communication network format, Internet-Protocol-

Based Mesh AMI communication network, Standardization of AMI:ANSI C12.22, IEC 62056, AMI and Distribution Management System Integration (DMI), Software Architecture and Evaluation of the MDI layer.

- **Privacy Preservation in Smart Grid** **08 hrs.**
  End- User Privacy: Introduction and Preliminaries to privacy preservation methods, K- Anonymity cloaking, Location obfuscation, Preliminary definitions, Privacy Preservation using location obfuscation methods, Preliminaries on Mobile nodes trajectory privacy, Location based services, Privacy preservation quantification: Probabilistic model, A vernoi-based location obfuscation method, Computing the instantaneous privacy level, concealing the movement path.
- **Management Aspects in Cyber Security** **08 hrs**
  System Administration policies, Security audit, Penetration testing and ethical hacking, Mandatory Access control, Discretionary Access Control, Monitoring and logging tools, Legal aspects.

Total Hours-45

3. <u>Books Recommended:</u>

1. Smart Grids: Security and Privacy Issues, Kianoosh G. Boroojeni, M.Hadi Amini, S.S. Iyengar, Springer, 2017.
2. Set Security and Privacy in Smart Grids, Yang Xiao, CRC Press Taylor & Francis Group, 2014.
3. Applied Cyber Security and the Smart Grid, E.D Knapp, Raj Samani, Elsevier-SYNGRESS.

4

5 AtulKahate – Cryptography and Network Security , 2nd Edition Tata McGraw Hill Publication, New Delhi-2006.

6 Behrouz A. Forouzan and D. Mukhopadhyay- Cryptography & Network Security, 2nd Edition - 1st reprint 2010, McGraw Hill, New Delhi.

7 Wade Trapple, Lawrence C. Washington- Introduction to Cryptography with coding Theory, 2nd Edition pearson Education.

8 Alfred J. Menezes, Paul C. van Oorschot and Scott A. Vanstone , Hand- book of Applied Cryptography, CRC Press.

9 Margaret Cozzens, Steven J Miller, The mathematics of encryption, American Mathematical Society.

M. Tech. Power System, Ist year, Semester II	L	T	P	Credit
ADVANCE POWER CONVERTERS FOR RENEWABLE ENERGY APPLICATIONS (Elective III)	**3**	**0**	**0**	**03**

EEPS118

1. Course Outcomes (COs):

At the end of the course, the students will be able to:

CO1	Analyze and understand power converter interfaced solar PV systems.
CO2	Select and design passive filters for grid-connected solar and wind systems.
CO3	Analyze and understand converter topologies for solar PV systems.
CO4	Analyze and understand converter topologies for wind turbine systems.
CO5	Design and analyze converter control for solar and wind turbine systems.

2. Syllabus

1. Power Converters for Solar PV Systems **18 hrs**

- **PV system classifications, requirements, and challenges**

  Standalone, grid-feeding and hybrid PV systems, Grid-feeding inverters: central, string and micro-Inverters, single-stage and two-stage inverter configurations, Grid requirements for PV, DC and AC side filtering requirements and design, issue of leakage/residual current and remedial techniques, Control structure: MPPT and grid-current control.
- **PV inverters derived from H-bridge topology**

  Basic full-bridge inverter, H5 inverter (SMA), HERIC inverter, REFU inverter, full-bridge inverter with DC Bypass (FB – DCBP), full-bridge Zero Voltage Rectifier (FB – ZVR)
- **High Voltage-Gain DC-DC Converters**

  Magnetic coupling based isolated/non-isolated converters, voltage multiplier cell, switched inductor and switched capacitor based converters, voltage lift converters, Z-source and resonant converters
- **PV Power Control**

  Grid Synchronization and PLL, MPPT & grid current control with above mentioned converters.

2. Power Converters for Wind Turbine (WT) Systems **20 hrs**

- **WT system classifications and requirements**

  Power conversion structures for variable speed wind turbine systems with IG, DFIG and PMSM; Grid requirements for WT systems, Conventional unidirectional and bi-directional power converters for WT systems.
- **Multilevel Power Converters**

  Three-Level Neutral-Point Diode Clamped Back-To-Back Topology (3L-NPC BTB), Three-Level H-Bridge Back-to-Back Topology (3L-HB BTB), Five-Level H-Bridge Back-to-Back Topology (5L-HB BTB), Three-Level Neutral-Point Diode Clamped Topology for Generator Side and Five-Level H-Bridge Topology for Grid Side (3L-NPC + 5L-HB).
- **Introduction to Matrix Converters:**

  Principle of operation, various configurations and applications.
- **Multi-input DC-DC Converters for Renewable Applications** **07 hrs**

  Various multi-input DC-DC converter topologies, their operations and applications

Total hours-45

3. **References:**

1. Remus Teodorescu et al, ``Grid converters for photovoltaic and wind power systems'', John Willey & Sons Ltd., 2011.
2. Sudipta Chakraborty et al, ``Power Electronics for Renewable and Distributed Energy Systems: A Sourcebook of Topologies, Control and Integration'', Springer Science & Business, 2013.
3. Ashok L. Kumar et al,`` Power electronic converters for solar photovoltaic systems'', Academic Press, 2020.
4. Nicola Femi et al, ``Power Electronics and control for maximum Energy Harvesting in Photovoltaic Systems'', CRC Press, 2013.

M. Tech. Power System, Ist year, Semester II

INSULATION ENGINEERING (Elective III)

EEPS120

L	T	P	Credit
3	0	0	03

1. **Course Outcomes (COs):**

At the end of the course, the students will be able to:

CO1	To describe the electrical insulation systems.
CO2	To illustrate Breakdown mechanisms in insulation.
CO3	To explain nano-dielectrics, multi stress aging, space charge.
CO4	To analyse Stochastic models of breakdown.
CO5	To design insulation systems.

2. **Syllabus**

- **Introduction** **06 hrs.**
  Dielectrics and electrical insulation systems used in high voltage power apparatus: gaseous, vacuum, liquid, solid and composite insulation, Behaviour of electrical insulation under electric stress.
- **Breakdown mechanisms in gaseous insulation** **04 hrs.**
  Ionization, attachment, Townsend and streamer theories, Paschen's law, partial breakdown, corona, time lags in breakdown, breakdown under impulse voltages, volt-time characteristics of breakdown,
- **Breakdown in vacuum** **03 hrs.**
- **Breakdown in liquid insulation** **03 hrs.**
- **Breakdown in solid and composite insulation** **04 hrs.**
- **Introduction to Nano dielectrics** **03 hrs.**
- **Space charge in dielectrics** **02 hrs.**
- **Electrical degradation** – treeing, partial discharge, tracking & erosion. **04 hrs.**
- **Stochastic models of breakdown** **05 hrs.**
- **Multi-stress ageing** **03 hrs.**
- **Design of insulation systems** used in various power apparatus (case studies) **08 hrs.**

Total Hours-45

3. **References:**

1. E.Kuffel, W.S.Zaengl, J.Kuffel, " High voltage Engineering Fundamentals" , Newnes, 2nd edition,2000.
2. M.S.Naidu, V. Kamaraju, "High voltage Engineering", TMH, 4th edition, 2009.
3. C L Wadhwa, "High voltage Engineering", New age International, 4th edition, 2021.
4. C L Wadhwa, "High voltage Engineering", New age International, 4th edition, 2021.

M. Tech. Power System, Ist year, Semester II

L	T	P	Credit
3	0	0	03

RENEWABLE ENERGY SOURCES (Elective IV)

EEPS142

1. **Course Outcomes (COs):**

At the end of the course, the students will be able to:

CO1	Explain the need of Renewable energy.
CO2	Analyze the different forms renewable energy sources
CO3	Explain principle and construction different renewable energy plants
CO4	Estimate the performance and efficiency of the different renewable energy sources plant.
CO5	Identify the applications of renewable energy sources
CO6	Select the appropriate location for harnessing renewable energy

2. **Syllabus**

- **wind Energy** **10 hrs.**

  Introduction to wind energy – basic principles of wind energy – conversion – power in the wind – maximum power – forces on the blade – wind energy conversion – small producers and large producers – wind data and (qualitative treatment only) energy estimation – site selection consideration – Basic components of wind energy conversion systems – classifications of WECS – advantages and disadvantages of WECS – generating system – scheme of electric generation – generator control - load control – energy storage – applications of wind energy – inter connecting system – environmental aspects – safety systems – prospects.

- **Solar Energy** **16 hrs.**

  Solar electric power generation – Principles of solar cells – semiconductor junctions – Conversion efficiency and power output – Photovoltaic system for power generation – Solar cell connecting arrangements – storage batteries – Inverters – applications of solar PV system.
  SOLAR THERMAL ENERGY: Introduction, Solar Thermal devices, Solar Pond. Solar thermal electric conversion.

- **Fuel Cells and Hydrogen Energy** **05 hrs**
  FUEL CELLS: Introduction –Types-Characteristics –Applications
  HYDROGEN ENERGY: Introduction –Production -Characteristics –Storage –Applications

- **Biomass Energy** **07 hrs**
  Introduction to biomass – Biomass conversion classification of biogas plants –Types of Biogas Plants Biogas from plant wastes – Community biogas plants – Materials used for biogas generation – selection of site for biogas plant –Fuel properties of biogas – utilization of biogas – methods of obtaining energy from Biomass Combustion.

- **Other Source of Energy** **07 hrs**
  GEOTHERMAL ENERGY: Introduction to Geothermal Energy –prime movers for Geothermal Energy conversion – classifications– Applications of Geothermal Energy at different temperatures - Geothermal Energy in India – prospects.
  OCEAN ENERGY :Introduction – Tidal Energy, Wave Energy, OTEC, Energy conversion to Electrical form - Characteristics –Applications
  MICRO HYDROPOWER: Introduction –Types- working- Characteristics –Applications

Total Hours-45

3. <u>Books Recommended:</u>

1 S. P. Sukhatme, “Solar Energy - Principles of thermal collection and storage”, TMH, 2008.
2 Thomas Ackermann, “Wind Power in Power System”, John Willey &Sons, 2005.
3 J. Twidell and T. Weir, “Renewable Energy Resources”, E & F N Spon Ltd, London, 1999.
4. Daniel, Hunt V, "Wind Power - A Handbook of WECS", Van Nostrend Co., New York, 1981.
5. Gary L. Johnson, "Wind Energy Systems", Prentice Hall Inc., 1985.

M. Tech. Power System, Ist year, Semester II

HVDC TRANSMISSION (Elective IV)

EEPS144

L	T	P	Credit
3	0	0	03

1. **Course Outcomes (COs):**

At the end of the course, the students will be able to:

CO1	To explain the configurations, advantages and applications of HVDC Transmission.
CO2	To analyse the operation of HVDC converters.
CO3	To analyse HVDC control methods for power flow.
CO4	To calculate the harmonics and filters parameters.
CO5	To analyse the Faults in HVDC System and their Protection.
CO6	To explain the Parallel Operation of AC-DC Systems.

2. **Syllabus**

- **Introduction to HVDC** **04 hrs.**
  Historical development in DC Transmission, Advantages & Disadvantages of DC Transmission over Ac Transmission, DC Transmission Systems: Mono-polar, bi-polar and homo-polar lines, back-to-back HVDC systems, Components of HDVC Transmission System, classification, Main applications of DC Transmission
- **Converter Operation** **11 hrs.**
  Choice of converter configuration, 6-pulse and 12-pulse rectifiers and inverters; Equivalent circuits of rectifier and inverter, relations between ac and dc quantities.
- **Converter charts** **04 hrs.**
  Charts with dc voltage and current as rectangular coordinates, charts with active and reactive powers as rectangular coordinates and their relation.
- **HVDC control systems** **06 hrs.**
  Constant current control, constant excitation angle control, VDCOL, constant ignition angle control, Individual phase control and equidistant pulse control; Valve blocking and by-passing; Starting, stopping and power flow reversal, advanced controller.
- **Harmonics and Filters** **06 hrs**.
  Characteristic and non-characteristic harmonics, input harmonics, output harmonics, problems due to harmonics, ac and dc filters.
- **Faults in HVDC system and their protection** **04 hrs.**
  DC line faults, clearing line faults, converter faults, ac system faults, rectifier side and inverter side faults; DC circuit breakers, overvoltage protection.
- **Parallel Operation of AC-DC Systems** **04 hrs.**
  Influence of ac system strength on ac-dc interaction, effective short-circuit ratio (ESCR), problems with low ESCR systems
- **Recent Developments in HVDC Transmission** **06 hrs.**
  Problems encountered with classical (CSC based) HDVC Transmission Systems and their overcome by VSC based HVDC systems, Operation Principle and control of VSC Based HVDC Transmission, VSC-HVDC Under AC and DC Fault Conditions.

Total Hours-45

3. **Books Recommended:**

1 E. Kimbark, Direct Current Transmission by Wiley International New York, 1971.
2 K.R. Padiyar, HVDC Power Transmission System, New Age International Private Limited, 2008.
3 E.Ulmann, Power Transmission by Direct Current, Springer-Verlag, 1975
4. P. Kundur, Power System stability and control, Tata McGraw Hill education, 1994.
5. J. Arrillaga, High Voltage Direct Current Transmission, IEE Power Engineering series, London, 1998
6. J. Arrillaga, Y. H. Liu and N. R. Watson, Flexible Power Transmission: The HVDC Option, John Wiley and Sons, New York, 2007
7. Nagwa F. Ibrahim and Sobhy S. Dessouky,Design and Implementation of Voltage Source Converters in HVDC Systems,Springer Nature, Switzerland,2021.
8. Chan-Ki Kim,Vijay K. Sood,Gil-Soo Jang,Seong-Joo Lim and Seok-Jin Lee, HVDC Transmission Power Conversion Applications in Power Systems, John Wiley & Sons,Singapore,2009.

M. Tech. Power System, Ist year, Semester II

ENERGY AUDIT (Elective IV)

EEPS146

L	T	P	Credit
3	**0**	**0**	**03**

1. **Course Outcomes (COs):**

At the end of the course, the students will be able to:

CO1	Explain the basics of energy audit methodology.
CO2	Classify different energy audit methodologies.
CO3	Analyze various electrical load management techniques
CO4	Perform the energy audit of motors and lighting systems
CO5	Asses the energy saving in different buildings
CO6	Use various software tools for energy audit studies

2. **Syllabus**

- **Global and Indian Energy Scenarios** **6 hrs.**
  Energy Scenario of India, Energy Strategy for the Future, basics of Energy Audit, Equipment required for Energy Audit: Electrical Measurement, Thermal Measurement, Light Measurement, Speed Measurement, Data Logger and Data-Acquisition System.
- **Types of Energy Audits and Energy-Audit Methodology** **12 hrs.**
  Definition of Energy Audit, Energy-Audit Methodology: Audit Preparation, Execution, Reporting. Financial Analysis, Sensitivity Analysis, Project-Financing Options, Energy Monitoring and Targeting.
- **Electrical-Load management** **6 hrs.**
  Electrical Basics, Electrical Load Management, Variable-Frequency Drives, Harmonics and Its Effects, Electricity Tariff for residential and commercial loads, Power Factor, Transmission and Distribution Losses.
- **Energy Audit of motors** **6 hrs.**
  Parameters Related to Motors, Efficiency of a motor, Energy conservation in motors, BEE Star Rating and Labelling
- **Energy Audit of Lighting Systems** **6 hrs**.
  Fundamentals of Lighting, Different Lighting Systems, Fixtures (Luminaries), Reflectors, Lenses and Louvers, Lighting Control Systems, Lighting System Audit, Energy-Saving Opportunities
- **Energy Audit Apllied to Buildings** **9 hrs.**
  Energy-Saving Measures in New Buildings, Water Audit, Audit Your Home, General Energy-saving Tips Applicable to New as Well as Existing Buildings, Introduction to Computer Software and Formats for Energy Audit.

Total Hours-45

3. **Books Recommended:**

1 Sonal Desai, “Handbook of Energy Audit”, 1st Edition, Tata McGraw Hill, 2015.

2 K V Sharma & P Venkataseshaiah, “Energy Management and Conservation”, 1st Edition, International Publishing House pvt.ltd, 2011.

3 Wayne C. Turner, Steve Doty, “Energy Management Handbook”, 6th Edition, CRC Press.

4 Murphy, W. R.,G McKay, “Energy Management”, Elsevier, 2007

M. Tech. Power System, Ist year, Semester II

ADVANCED ENERGY STORAGE DEVICES AND APPLICATIONS (Elective IV)

EEPS148

L	T	P	Credit
3	0	0	03

1. Course Outcomes (COs):

At the end of the course, the students will be able to:

CO1	Describe different energy storage technology and compare them based on their performance
CO2	Modelling of various electrochemical storage devices and develop suitable battery management system
CO3	Discuss electrical and magnetic storage systems and describe hydrogen and fuel cells
CO4	Detailed understanding of thermal and mechanical storage and analyze energy savings
CO5	Explain and illustrate hydrogen and fuel cells
CO6	Describe different energy storage technology and compare them based on their performance

2. Syllabus

- **Introduction to energy storage** **5 hrs.**
  Relevance and scenario, perspective on development of energy storage systems, energy storage criteria, general concepts, fundamentals and applications, energy storage technologies, future prospect of storage, Ragone plots
- **Electrochemical energy storage** **10 hrs.**
  Battery technologies and different battery chemistry, electrode materials, electrolytes. performance comparison, reaction mechanism, practical parameters, technical characteristics, equivalent circuit. Testing, standards and system sizing, battery storage integration.
- **Battery management system (bms)** **10 hrs.**
  BMS functionality, requirements; State Estimation: definitions and their estimation methods; SOH estimation: predictive SOH models, aging, capacity estimation, self-discharge detection, parameter estimation, remaining useful life estimation; Cell balancing: causes of imbalancing, balancing strategies, charge transfer balancing-design choices, circuits for balancing; thermal management of battery; case study
- **Electrical and magnetic storage systems** **8 hrs.**
  Supercapacitors: basics, technical characteristics, equivalent circuit, electrode material, pseudocapacitive energy storage, energy storage devices, applications and challenges; Magnetic Systems- energy storage in superconducting magnetic systems, superconductive materials, applications.
- **Fuel cells and hydrogen storage** **06 hrs**
  Fuel cell: working, basic components, principle, thermodynamics of fuel cell, types, challenges; Hydrogen storage-hydrogen as an energy vector and basic principles, hydrogen production, strategies for storing energy in hydrogen, applications.
- **Thermal and mechanical storage** **06 hrs**
  Basic principle, criteria for TES evaluation, operating characteristics, standards, phase change materials, sensible TES- passive and active systems, design and thermal stratification, energy and exergy analyses, efficiency measures. Mechanical storage: flywheel, pumped hydropower storage and compressed-air energy storage, comparison and application, principle of operation, function and deployments; case study

Total Hours-45

3. Books Recommended:

1 1. Robert A. Huggins, “Energy storage”, Springer Nature, 2nd edition, 2016.

2 Christopher D. Rahn, and Chao-Yang Wang, “Battery systems engineering”, John Wiley & Sons, 2013.

3 Ibrahim Dincer, and Marc A. Rosen, “Thermal energy storage: systems and applications” John Wiley & Sons, 3rd edition, 2021

4 Gregory L. Plett, “Battery management systems, Volume II: Equivalent-circuit methods”, Artech House, 2015.

5 Phil Weicker, “A systems approach to lithium-ion battery management”, Artech house, 2013.

6 F. Barnes and J. Levine. "Large energy storage systems", CRC press, 2011.

M. Tech. Power System, I[st] year, Semester II

WIDE AREA POWER SYSTEM CONTROL (Elective IV)

EEPS150

L	T	P	Credit
3	0	0	03

1. **Course Outcomes (COs):**

At the end of the course, the students will be able to:

CO1	Explain various Synchrophasor Measurement Techniques
CO2	Implement and test wide area measurement systems
CO3	Realize optimal placement of PMU and state estimation using PMU data
CO4	Monitor, analyse and control power system conditions in real time
CO5	Interpret wide area PMU measurements
CO6	At the end of the course, the students will be able to:

2. **Syllabus**

- **PHASOR MEASUREMENT TECHNIQUES** **12 hrs.**
  Phasor Measurement Techniques: Basic Concepts and Definitions SCADA vs PMU, Synchrophasors, Frequency, and ROCOF, Steady-State and Dynamic Conditions in Power Systems, Classical Phasor Versus Dynamic Phasor, Basic Definitions of Accuracy Indexes, Algorithms for Synchrophasors, Frequency, and ROCOF, Methods to Calculate Synchrophasors based on a Steady-State Model and Dynamic Signal Model, Evaluation of Frequency and ROCOF, Dynamic Behavior of Phasor Measurement Algorithms.

- **PHASOR MEASUREMENT UNITS AND PHASOR DATA CONCENTRATORS** **10 hrs**
  Phasor measurement units and Phasor data concentrators: WAMS architecture, Sensors for PMUs, International Standards for Instrument Transformers, Accuracy of Instrument Transformers, Transducer Impact on PMU Accuracy, Hardware for PMU and PMU Integration, PMU Architecture, Data Acquisition System, Synchronization Sources, Communication and Data Collector, Distributed PMU, International Standards for PMU and Tests for Compliance, IEC 61850.

- **STATE ESTIMATION** **12 hrs.**
  State Estimation and PMUs: Formulation of the SE Problem, Network Observability-SE Measurement Model, SE Classification, State estimation with phasor measurents, Linear state estimation, Dynamic estimators. Optimal PMU placement, meta-heuristic and deterministic algorithms, Integer Linear Programming Technique.

- **WIDE AREA MONITERING SYSTEM** **11 hrs.**
  WAMS applications- real-time analysis and technologies to detect, locate and characterize power system disturbances, monitoring power system oscillatory dynamics- Interpretation and visualization of wide-area PMU measurements, power system control with phasor feedback, discrete event control.

Total Hours-45

3. **Books Recommended:**

1. Antonello Monti, Carlo Muscas, Ferdinanda Ponci, Phasor Measurement Units and Wide Area Monitoring Systems, Academic Press, 2016.
2. A.G. Phadke, J.S. Thorp, Synchronized Phasor Measurement and Their Applications, Springer 2008.
3. Yong Li, Dechang Yang, Fang Liu, Yijia Cao, Christian Rehtanz, Interconnected Power Systems: Wide-Area Dynamic Monitoring and Control Applications, Springer, 2015.
4. Ali Abur, Antonio Gómez Expósito, Power System State Estimation: Theory and Implementation, CRC Press, 2004.
5. Ma J., Makarov Y., Dong Z, Phasor Measurement Unit and its Applications on Modern Power Systems, Springer, 2010.

M. Tech. Power System, Ist year, Semester II	L	T	P	Credit
ADVANCED OPTIMIZATION METHODS	**3**	**0**	**0**	**03**

EEPS172

1. Course Outcomes (COs):

At the end of the course, the students will be able to:

CO1	Explain the basic principle of optimization.
CO2	Derive the equations and solution through linear programming method.
CO3	Estimate the performance of traditional optimization method.
CO4	Analyse the performance of constrained optimization algorithms.
CO5	Analyse the induction of non-traditional optimization algorithms.
CO6	Apply the optimization method in real world.

2. Syllabus

- **Introduction** **04 hrs.**
  Historical Development, Engineering application of Optimization, Formulation of design problems, Classification of optimization problems.
- **Linear programming** **08 hrs.**
  Theorem of Linear programming problems and Relation to convexity, Simplex method, Revised simplex method, Duality in linear programming(LP), Sensitivity analysis, other algorithms for solving LP problems.
- **Single and Multivariable Optimization** **09 hrs.**
  Single variable: Optimality criteria, Bracketing Methods, Region Elimination Method, Gradient Based methods: Newton-Raphson Method, Bisection Method, Secant Method; Multivariable: Optimality criteria, Direct Search Methods, Gradient Based Methods: Steepest Descent Method, Conjugate Gradient Method, Quasi-Newton Method, Variable Metric Method, applications.
- **Constrained Optimization Techniques** **08 hrs.**
  Characteristics of a constrained problem, Variable Elimination Method, Lagrange Multiplier, Kuhn-Tucker Conditions, Frank-Wolfe Method, Cutting plane Method, penalty function Methods, application.
- **Advanced Optimization Techniques** **16 hrs**.
  Introduction to Multi objective Optimization, Swarm intelligences, Genetic Algorithm, Teaching Learning Based Optimization, Rao algorithms and other Non-traditional Optimization Algorithms, applications.

Total Hours-45

3. Books Recommended:

1 S. S. Rao, ‘Engineering “Optimization theory and applications”, Fourth Edition, John Wiley and Sons, 2009.

2 Kalyanmoy Deb, “Optimization for Engineering Design: Algorithms and Examples” Prentice-Hall of India Pvt.Ltd.,2005

3 M.S. Bazaraa, H.D. Sheraliand C.Shetty, “Nonlinear Programming, Theory and Algorithms”, John Wiley and Sons, New York, 1993

4. Ke-Lin Du and M.N.S. Swamy, “Search and Optimization by Metaheuristics Techniques and Algorithms Inspired by Nature,” Springer International Publishing Switzerland, 2016

5. R. Venkata Rao, Teaching Learning Based Optimization Algorithm and Its Engineering Applications, Springer International Publishing Switzerland, 2016
6. Kwang Y. Lee and Mohamed and A. El-Sharkawi, Modern Heuristic Optimization Techniques Theory and Applications To Power Systems, John Wiley & Sons, Inc., Hoboken, New Jersey, 2008
7. Gang Lei, Jianguo Zhu and Youguang Guo, "Multidisciplinary Design Optimization Methods for Electrical Machines and Drive Systems," Springer-Verlag Berlin Heidelberg 2016
8. Rangrajan K. Sundaram, "A First Course in Optimization Theory", Cambridge University Press,1996
9. A.Ravindran, K.M. Ragsdell, G.V. Reklaitis, "Engineering Optimization Methods and Applications", Wiley India Pvt.Ltd., 2006
10. E.S. Gopi, "Algorithm Collections for Digital Signal Processing Applications Using MATLAB," Springer, Dordrecht, The Netherlands,2007

M. Tech. Power System, Ist year, Semester II

ADVANCED NUMERICAL METHODS

EEPS174

L	T	P	Credit
3	0	0	03

1. Course Outcomes (COs):

At the end of the course, the students will be able to:

CO1	Learn various advanced numerical methods.
CO2	Apply the numerical methods for solving problems related to electrical engineering.
CO3	Modeling various systems and perform regression analysis.
CO4	Analyse the convergence rate and stability of the algorithms
CO5	Select a suitable numerical method for solving the real time problems based on the accuracy, speed and stability.

2. Syllabus

- **Error Analysis** **04 hrs.**
  propagation of error, fixed point and floating-point algorithms, reminder theorem
- **Solution Of System of Nonlinear Equations** **06 hrs.**
  Newton-Raphson method, Method of Successive approximation, Adomian decomposition method, convergence criterion
- **Regression Analysis** **12 hrs.**
  Least Square criterion (LSq), two-dimensional regression for linear and nonlinear systems, multi-dimensional regression for linear and nonlinear systems
- **Solution To Ordinary Differential Equations** **12 hrs.**
  Single-step and multi-step explicit integration algorithms – Adam's Bashforth formula, multi-step implicit integration algorithms – Adam's Moulton formula, stability analysis.
- **Solution To Partial Differential Equations** **06 hrs.**
  Specification of initial and boundary conditions, Solution by finite difference method
- **introduction to integral equations** **05 hrs.**
  Homogenous and non-homogenous integral equations, numerical methods to solve solution to integral equations

Total Hours-45

3. Books Recommended:

1 Shastri S. S., "Introductory Methods of Numerical Analysis", Prentice Hall Ltd., 4th Edition, 2005.

2 Jain M. K., Iyengar S.R.K., Jain R.K., "Numerical Methods for Scientific and Engineering Computation", 4th Edition, 2003, New Age international Publishers, Pvt. Ltd.

3. S. D. Conte and Carl de Boor, Elementary Numerical Analysis an Algorithmic Approach, 3rd Edition, McGraw- Hill, 1980.

4. Pallab Ghosh, "Numerical Methods with Computer Programs", in C++, Printice Hall of India Private Ltd., 2006.

5. Teukolsky S. A., Vetterling W. T., Press W. H. & Flannery B. P., "Numerical recipes in 'C', 2nd Edition,

6. Leon O. Chua and Pen-Min Lin, "Computer-Aided Analysis of Electronic Circuits", Printice Hall Series in Electrical and Computer Engineering

M. Tech. Power System, Ist year, Semester II

L	T	P	Credit
3	0	0	03

ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

EEPS176

1. Course Outcomes (COs):

At the end of the course, the students will be able to:

CO1	Explain the fundamental issues and challenges of Artificial Intelligence.
CO2	Analyze various Machine learning algorithms.
CO3	Compare machine learning/artificial intelligence approaches.
CO4	Apply various Machine learning methods.
CO5	Develop ANN/FL algorithms and models.
CO6	Implement various machine learning algorithms in real-world applications.

2. Syllabus

- **Introduction to Machine learning (ML)** **10 hrs.**
  Identification in the Limit, Oracle Based Learning, Probably Approximately Correct (PAC) Model, Boosting Bayesian Learning: Maximum Likelihood, Estimates, Parameter Estimation. Types of Machine learning – Basic Concepts in Machine Learning - SUPERVISED LEARNING: Linear Models for Classification: Discriminant Functions - Probabilistic Generative Models - Probabilistic Discriminative Models - Bayesian Logistic Regression, linear models, Logistic Regression, Generalized Linear Models, Unsupervised learning, clustering: K-means/Kernel K-means, Dimensionality, Reduction: PCA and kernel PCA, Evaluating Machine Learning algorithms and Model Selection, Ensemble Methods (Boosting, Bagging, Random Forests), Modelling Sequence /Time- Series Data, Deep Learning and Feature Representation, Learning, Scalable Machine Learning (Online and Distributed Learning)
- **Introduction to Artificial intelligence (AI)** **10 hrs.**
  Computerized reasoning – Artificial Intelligence (AI) – characteristics of an AI problem – Problem representation in AI – State space representation – problem reduction, Concept of small talk programming, Knowledge representation issues, predicate logic- logic programming, semantic nets- frames and
  inheritance, constraint propagation, representing knowledge using rules, rules based deduction systems, Reasoning under uncertainty, review of probability, Baye's probabilistic interferences and Dempster Shafer theory.
- **Artificial Neural Networks (ANN)** **10 hrs.**
  Feed forward Network Functions - Error Backpropagation -Regularization in Neural Networks – Mixture Density Networks – Bayesian Neural Networks. Kernel Methods – Dual Representations – Radial Basis Function Networks – Ensemble learning: Boosting – Bagging. Forecasting models using ANN, Trend analysis, Cyclical and Seasonal analysis, smoothing; Moving averages; Box-Jenkins, Holt-winters, Auto-correlation; ARIMA, Examples: Applications of Time Series in financial markets.
- **Fuzzy logic** **7 hrs.**
  Reasoning in uncertain environments, Fuzzy logic, fuzzy composition relation, operations on fuzzy sets, fuzzification - defuzzification, fuzzy decision making, fuzzy logic controllers, Fuzzy

Classification: Classification by equivalence relations-crisp relations, Fuzzy relations, Cluster analysis, Cluster validity, C-Means clustering, Hard C-Means clustering, Fuzzy C-Means algorithm, Classification metric, Hardening the Fuzzy C-Partition.

- **Application** **8 hrs**.
  Examples of Machine Learning Applications – Linear Models for Regression – Linear Basis Function Models – The Bias-Variance Decomposition – Bayesian Linear Regression – Bayesian Model Comparison. Radar for target detection, Deep Learning Automated ECG Noise Detection and Classification, ML in Network for routing, traffic prediction and classification, Application of ML in Cognitive Radio Network (CRN).

Total Hours-45

3. <u>Books Recommended:</u>

1 Timothy J.Ross - Fuzzy logic with engineering applications, 3rd edition, Wiley,2010.
2 George J.KlirBo Yuan - Fuzzy sets and Fuzzy logic theory and Applications, PHI, New Delhi,1995
3 Applied Machine Learning, M. Gopal, McGraw Hill Education
4. Machine Learning March 1997, Thomas M. Mitchell, McGraw-Hill, Inc. 2. Neural Networks: A Comprehensive Foundation, Simon Haykin, Prentice Hall
5. Neural Network Design, M. T. Hagan, H. B. Demuth, Mark Beale, Thomson Learning, Vikash Publishing House
6. Patrick Henry Winston, "Artificial Intelligence", Addison Wesley, 2000.
7. Luger George F and Stubblefield William A, "Artificial Intelligence: Structures and Strategies for Complex Problem Solving", Pearson Education, 2002.
8. Christopher Bishop, "Pattern Recognition and Machine Learning" Springer, 2007.
9. Kevin P. Murphy, "Machine Learning: A Probabilistic Perspective", MIT Press, 2012.
10. Ethem Alpaydin, "Introduction to Machine Learning", MIT Press, 3rd Edition, 2014
11. Sayed, A.H., 2014. Adaptation, learning, and optimization over networks. Foundations and Trends" in Machine Learning, 7(4-5), pp.311-801.

M. Tech. Power System, Ist year, Semester II

RELIABILITY EVALUATION OF ELECTRICAL SYSTEMS

EEPS178

L	T	P	Credit
3	0	0	03

1. **Course Outcomes (COs):**

At the end of the course, the students will be able to:

CO1	The students would be able understand the basic of reliability and its importance for electrical network.
CO2	The students would be able to implement and model for reliability evaluation of generating systems for LOLE and reliability indices.
CO3	The students would be able to calculate the duration and frequency of outages and availability from reliability.
CO4	The students would be able to evaluate the impact of interconnections on reliability.
CO5	The students would be able to extend the concept of reliability for electrical distribution network for its secure and safe operation with relays, circuit breakers, switches etc.
CO6	The Monte Carlo simulation concept would be implemented for electrical networks for verification and execution of reliability indices.

2. **Syllabus**

- **Introduction** **04 hrs.**
  Background, types of systems, qualitative and quantitative assessment and its uses, reliability definition and criteria, reliability indices, reliability evaluation techniques, reliability economics, data, monitoring and growth, Probabilistic reliability criteria for electrical network, Statistical and probabilistic measures, Absolute and relative measures, Methods of assessment, Concepts of adequacy and security, System analysis, Reliability cost and reliability worth Concepts of data
- **Generating capacity-basic probability methods** **08 hrs.**
  Introduction, The generation system model, Generating unit unavailability, Capacity outage probability tables, Comparison of deterministic and probabilistic criteria, A recursive algorithm for capacity model building, Recursive algorithm for unit removal, Alternative model-building techniques, Loss of load indices, Concepts and evaluation techniques, Numerica1 examples, Equivalent forced outage rate, Capacity expansion analysis, Evaluation techniques, Perturbation effects, Scheduled outages, Evaluation methods on period bases, Load forecast uncertainty, Forced outage rate uncertainty, Exact method, Approximate method, Application, LOLE computation, Additional considerations, Loss of energy indices, Evaluation of energy indices, Expected energy not supplied, Energy-limited systems, Practical system studies, Conclusions, Problems
- **Generating capacity-frequency and duration method** **08 hrs.**
  Introduction, The generation model, Fundamental development, Recursive algorithm for capacity model building, System risk indices, Individual state load model, Cumulative state load model, Practical system studies, Base case study, System expansion studies, Load forecast uncertainty, Conclusions, Problems.
- **Interconnected systems** **08 hrs.**
  Introduction, Probability array method in two interconnected systems, Concepts , Evaluation techniques, Equivalent assisting unit approach to two interconnected systems, Factors affecting the

emergency assistance available through the interconnections, Introduction, Effect of tie capacity, Effect of tie line reliability, Effect of number of tie lines, Effect of tie-capacity uncertainty, Effect of interconnection agreements, Effect of load forecast uncertainty, Variable reserve versus maximum peak load reserve, Reliability evaluation in three interconnected systems, Direct assistance from two systems, Indirect assistance from two systems, Multi-connected systems.

- **Distribution systems-basic techniques and radial networks** 10 **hrs**.
  Introduction, Evaluation techniques, Additional interruption indices, Concepts, Customer-orientated indices, Load- and energy-orientated indices, System performance, System prediction, Application to radial systems, Effect of lateral distributor protection, Effect of disconnects, Effect of protection failures, Effect of transferring loads, No restrictions on transfer, Transfer restrictions, Probability distributions of reliability indices, Concepts, Failure rate, Restoration times, conclusions, problems.
- **Applications of Monte Carlo simulation** **07 hrs.**
  Introduction, Types of simulation, Concepts of simulation, Random numbers, Simulation output, Application to generation capacity reliability evaluation, Introduction, Modelling concepts , LOLE assessment with non-chronological load, LOLE assessment with chronological load, Reliability assessment with non-chronological load, Reliability assessment with chronological load, Application, to distribution systems, Introduction, Modelling concepts, Numerical examples for radial networks, Numerical examples for meshed (parallel) networks, Extensions to the basic approach, Conclusions, Problems.

Total Hours-45

3. <u>Books Recommended:</u>

1 Reliability evaluation of power systems, Roy Billinton, Ronald N. Allan, Springer
2 Reliability evaluation of engineering systems, Roy Billinton, Ronald N. Allan, Springer
3 Distribution reliability, and power quality, t. A. Short, taylor & francis group
4. Reliable and sustainable Electric Power and Energy Systems Management, Roy Billinton, Ajit Kumar Verma, Rajesh Karki, Springer

M. Tech. Power System, Ist year, Semester II

ENERGY STORAGE AND MANAGEMENT

EEPS180

	L	T	P	Credit
	3	**0**	**0**	**03**

1. Course Outcomes (COs):

At the end of the course, the students will be able to:

CO1	Describe and compare different energy storage technology and their performance.
CO2	Model various electrochemical storage devices and develop suitable battery management system.
CO3	Identify electrical and magnetic storage systems and their applications.
CO4	Explain and illustrate hydrogen and fuel cells.
CO5	Classify and analyse thermal and mechanical storage systems.
CO6	Design operational strategies for off-grid and on-grid energy storage applications.

2. Syllabus

- **Introduction to Energy Storage** **03 hrs.**
  Relevance and scenario, perspective on development of energy storage systems, energy storage criteria, general concepts, fundamentals and applications, energy storage technologies, Ragone plots, future prospect
- **Electrochemical Energy Storage** **06 hrs.**
  Battery technologies and different battery chemistry, electrode materials, electrolytes, performance comparison, reaction mechanism, practical parameters, technical characteristics, equivalent circuit, testing, standards and system sizing, battery storage integration.
- **Battery Management System (BMS)** **10 hrs.**
  BMS functionality, requirements; State Estimation: definitions and their estimation methods; SOH estimation: predictive SOH models prediction models and remaining useful life estimation; Cell balancing: causes of imbalancing, balancing strategies, charge transfer balancing-design choices, circuits for balancing; thermal management of battery; case study.
- **Electrical and Magnetic Storage Systems** **09 hrs.**
  Devices, electrode materials, electrolytes, reaction mechanism, practical parameters, equivalent circuit, testing, standards and system sizing, balancing circuit, applications and challenges; Magnetic Systems- energy storage in superconducting magnetic systems, superconductive materials, applications.
- **Fuel Cells and Hydrogen storage.** **04 hrs**.
  Supercapacitors: Fuel cell: working, basic components, principle, thermodynamics of fuel cell, types, challenges**;** Hydrogen storage-hydrogen as an energy vector and basic principles, hydrogen production, strategies for storing energy in hydrogen, applications.
- **Thermal and Mechanical Storage.** **08 hrs.**
  Basic principle, criteria for TES evaluation, operating characteristics, standards, phase change materials, sensible TES, design and thermal stratification, energy and exergy analyses; Mechanical storage: flywheel, pumped hydropower storage and compressed-air energy storage, comparison and application, principle of operation, function and deployments; case study.
- **Energy Storage Integration and Its Application** **04 hrs.**
  Energy policy and markets, energy storage planning and operation, application and challenges, case study.

Total Hours-45

3. Books Recommended:

1 Robert A. Huggins, "Energy storage", Springer Nature, 2nd edition, 2016.
2 Christopher D. Rahn, and Chao-Yang Wang, "Battery systems engineering", John Wiley & Sons, 2013.
3 Ibrahim Dincer, and Marc A. Rosen, "Thermal energy storage: systems and applications" John Wiley & Sons, 3rd edition, 2021.
4. Gregory L. Plett, "Battery management systems, Volume II: Equivalent-circuit methods", Artech House, 2015.
5. Phil Weicker, "A systems approach to lithium-ion battery management", Artech house, 2013.
6. F. Barnes and J. Levine. "Large energy storage systems", CRC press, 2011.

7. Trevor M. Letcher, Richard Law, and David Reay, “Storing energy: with special reference to renewable energy sources” Vol. 86. Amsterdam: Elsevier, 2016.

Hands-on training: Finite Element Methods in High Voltage Engineering

M. Tech. (Electrical) (Power Systems) (METMV02) **Hands-on training: Finite Element Methods in High Voltage Engineering**	**Scheme**	**L**	**T**	**P**	**Credit**
		0	**0**	**10**	**5**

Course outcomes:

At the end of this course the students will be able to

CO1	Explain Finite Element Method (FEM)
CO2	Develop model using FEM
CO3	Compute electrostatic and electromagnetic field in various model using FEM
CO4	Control electrostatic and electromagnetic field in various model of FEM
CO5	Design and analysis inductor, transformer, rotating electrical machines using FEM

Sl. No.	**Theory Topics**	**Hours**
1.	**Introduction** Review of Electromagnetic Field Theory. Review of High Voltage Engineering. Review of Electrical Machine Design	4
2.	**Electrostatic Field Computation** Estimation and Control of Electric Stress	4
3.	**Numerical Methods for Electric Field Computation** Finite Element Method, Charge Simulation Method, Boundary Element Method	6
4.	**Electromagnetic Field Computation** Inductor, Transformer and Rotating Electrical Machine	6

List of the FEM based experiments:

Sl. No.	**Name of the FEM based Experiments**	**Hours**
8.	Introduction to Commercial FEM software	10
9.	Modelling and Electrostatic field computation in various electrode systems	10
10.	Modelling and Electrostatic field computation in single phase and three phase Cable, Capacitor, Overhead Transmission Line	20
11.	Modelling and Electromagnetic field computation in air core inductor	10
12.	Modelling and Electromagnetic field computation in Inductor, Transformer, Rotating Electrical Machines	20
13.	Design of Inductor	10
14.	Estimation and Control of electrostatic and electromagnetic stresses in Inductor	10

15.	Design of Transformer	10
16.	Estimation and Control of electrostatic and electromagnetic stresses in Transformer	10
17.	Design of Rotating Electrical Machines	20
18.	Estimation and Control of electrostatic and electromagnetic stresses in Rotating Electrical Machines	20
19.	Continuous Evaluation	30
	Total (Notional Hours)	200