Annexure-I

SARDAR VALLABHBHAI NATIONAL INSTITUTE OF TECHNOLOGY, SURAT

DEPARTMENT OF ELECTRICAL ENGINEERING

M. Tech. Programme
In
Power Systems
Course Structure and Scheme of Evaluation (Semester-wise)

SEMESTER – I

Sr. No.	Course Code	Course	L	T	P	Credits	Examination Scheme				
			Hrs	Hrs	Hrs		Theory Marks	Tutorial Marks	Termwork Marks	Practical Marks	Total Marks
1	EL619	Computer Aided Power System Analysis	3	1	2	05	100	25	20	30	175
2	EL621	Power System Protection	3	1	2	05	100	25	20	30	175
3	EL623	Power Electronics	3	0	2	04	100	00	20	30	150
4	EL625	Restructuring in Power Systems	3	0	0	03	100	-	-	-	100
5	ELXXX	Elective I	3	0	0	03	100	-	-	-	100
		TOTAL	**15**	**2**	**6**	**20**	**500**	**50**	**60**	**90**	**700**
		TOTAL	**23**			**20**					

Elective I

(From amongst the electives one subject will be offered to each group of candidates)

EL627	Automation and Instrumentation for Power Systems
EL629	Microcontroller Based System Design
EL631	Digital Signal Processing
EL633	Optimization Methods
EL635	Linear algebra

SEMESTER – II

Sr. No.	Course Code	Course	L	T	P	Credits	Examination Scheme				
			Hrs	Hrs	Hrs		Theory Marks	Tutorial Marks	Termwork Marks	Practical Marks	Total Marks
1	EL620	Power System Dynamics and Control	3	0	2	04	100	00	20	30	150
2	EL622	High Voltage Engineering & EHV Transmission	3	1	2	05	100	25	20	30	175
3	EL624	Renewable Energy Sources	3	1	0	04	100	25			125
4	EL626	Applications of Power Electronics in Power Systems	3	0	2	04	100	-	20	30	150
5	ELXXX	Elective II	3	0	0	03	100	-	-	-	100
		TOTAL	**15**	**2**	**6**	**20**	**500**	**50**	**60**	**90**	**700**
		TOTAL	**23**			**20**					

Elective II

(From amongst the electives one subject will be offered to each group of candidates)

EL628	Electrical Drives
EL630	High Voltage DC Transmission
EL632	Modern Control Systems
EL634	Power System Transients
EL636	Distributed Generation

SEMESTER – III

Sr. No.	Course Code	Course	L	T	P	Credits	Examination Scheme				
			Hrs	Hrs	Hrs		Theory Marks	Tutorial Marks	Termwork Marks	Practical Marks	Total Marks
1	EL701	Seminar	0	0	4	02	-	-	20	30	50
2	EL703	Dissertation Preliminary	0	0	16	08	-	-	100	150	250
		TOTAL	**0**	**0**	**20**	**10**	**-**	**-**	**120**	**180**	**300**
		TOTAL	**20**								

SEMESTER – IV

Sr. No.	Course Code	Course	L	T	P	Credits	Examination Scheme				
			Hrs	Hrs	Hrs		Theory Marks	Tutorial Marks	Termwork Marks	Practical Marks	Total Marks
1	EL702	Dissertation	0	0	24	12	-	-	160	240	400
		TOTAL	**0**	**0**	**24**	**12**	**-**	**-**	**160**	**240**	**400**
		TOTAL	**24**								

Total : 62 credits

M.Tech (Power Systems) Semester-I	L	T	P	C
EL619: COMPUTER AIDED POWER SYSTEM ANALYSIS	3	1	2	5

- **SOLUTION OF LINEAR SYSTEMS** **(04 Hours)**

  Matrix representation of power systems, Triangularization, Gaussian elimination, LU and LDU factorization LDL^T decomposition for sparse Matrices, Optimal ordering.

- **LOAD FLOW ANALYSIS** **(08 Hours)**

  Newton–Raphson iteration, Power system applications: Power flow, Formulation of Bus admittance matrix, regulating transformers, Gauss-Siedel, Newton-Raphson and Fast Decoupled methods of power flow, Treatment of voltage controlled buses, Accelerating factors, DC load flow.

- **SHORT CIRCUIT STUDIES** **(08 Hours)**

  System Representation, Algorithm for formation of bus impedance matrix, Balanced fault, Sequence impedances of power system components, Unbalanced fault Analysis.

- **LOAD FREQUENCY CONTROL** **(05 Hours)**

  Automatic Load Frequency Control of Single Area System and Multi Area System, Steady State Instabilities,

- **POWER SYSTEM STATE ESTIMATION** **(06 Hours)**

  Power system state estimator, Method of Least Squares, Statistics, Errors and Estimates, Test for bad data, Network Topology Processing.

- **OPTIMAL POWER FLOW** **(05 Hours)**

  Introduction, Solution of OPF, Linear Sensitivity Analysis, Linear Programming methods, Security Constrained OPF

- **UNIT COMMITMENT AND CONTIGENCY ANALYSIS** **(06 Hours)**

  Constraints in UC, Solution Methods of UC, Overview of Security Analysis, Linear Sensitivity Factors, Contingency Selection, Calculation of Network Sensitivity Factors.

Total Hours:42

BOOKS RECOMMENDED:

1. Hadi Saadat, “Power System Analysis”, Tata Mc Graw Hill, 2003.
2. A. J. Wood and B.F. Wollenberg, “Power Generation Operation and Control”, John Wiley & Sons, ICN., 2nd Edition.
3. A. K.Mahalanabis, “Computer Aided Power system analysis and control”, Tata McGraw Hill 1991
4. John J. Grainger, William D. Stevenson, JR. “ Power System Analysis”, McGraw Hill, 1994.
5. Elgerd ollel, “Electric Energy Sytems Theory- An Introduction”, Tata Mc Graw Hill, 2ed. 1995
6. I. J. Nagrath & D.P. Kothari, “Modern Power System Analysis”, Tata McGraw Hill,1989
7. Wadhwa C L, “Electrical Power Systems”, New Age Publication, 3ed., 2002

M.Tech (Power Systems) Semester-I	L	T	P	C
EL621: POWER SYSTEM PROTECTION	3	1	2	5

- **REVIEW OF PRINCIPLES OF POWER SYSTEM PROTECTION** **(04 Hours)**

  General philosophy of protection, Relay terminology, Review of Relay characteristics, Classification of Relays, characteristics and operating equation.

- **INSTRUMENT TRANSFORMER FOR RELAYING** **(04 Hours)**

  Performance of conventional CT/PT as well as capacitive voltage transformers. Principle of operation of magneto optic CT/ PT. Standards, effect on relaying philosophy.

- **SYMMETRICAL COMPONENTS** **(05 Hours)**

  Positive, Negative and Zero sequence set, Sequence networks, Shunt and series unbalance sequence network interconnections, Simultaneous unbalances.

- **APPARATUS PROTECTION** **(15 Hours)**

  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** **(14 Hours)**

  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: 42

BOOKS RECOMMENDED:

1. Bhuvanesh Oza, N.C. Nair, R.P.Mehta, V.H.Makwana “Power System Protection and Switchgear”, Tata Mc Graw Hill, 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

M.Tech (Power Systems) Semester-I	L	T	P	C
EL623: POWER ELECTRONICS	3	0	2	4

- **REVIEW OF POWER SEMICONDUCTOR DEVICES** **(10 Hours)**

  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.

- **DC-DC CONVERTERS** **(10 Hours)**

  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** **(12 Hours)**

  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** **(08 Hours)**

  Principle of phase control, Review of single phase converters, 3 phase half and fully controlled converters, 12–pulse converter, Dual converters.

- **AC VOLTAGE CONTROLLERS** **(02 Hours)**

  Single phase AC voltage controllers, 3–phase AC voltage controllers.

Total Hours: 42

BOOKS RECOMMENDED:

1. Rashid, M. H., "Power Electronics Circuits, Devices, and Applications, Prentice-Hall of India Pvt. Ltd., New Delhi, 2nd edition, 1999.
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. Erickson Robert W., Maksimovic Dragan, "Fundamentals of Power Electronics", Kluwer Academic Publishers Group (Netherlands), 2001.
5. A. Pressman, “Switching Power Supply Design”, McGraw-Hill, 1998.

M.Tech. (Power systems), Semester – I	L	T	P	C
EL625: RESTRUCTURING IN POWER SYSTEMS	3	0	0	3

- **DEREGULATION OF THE ELECTRICITY SUPPLY INDUSTRY** **(06 Hours)**

  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, implementation of deregulation in India and its proposed structure

- **POWER SYSTEM OPERATION IN COMPETITIVE ENVIRONMENT** **(10 Hours)**

  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** **(09 Hours)**

  Power wheeling, Transmission open access, pricing of power transactions, security management in deregulated environment, congestion management in deregulation

- **ANCILLARY SERVICES MANAGEMENT** **(08 Hours)**

  General description of some ancillary services, ancillary services management in various countries, reactive power management in deregulated electricity markets (Case study)

- **RELIABILITY AND DEREGULATION** **(06 Hours)**

  Reliability analysis: interruption criterion, stochastic components, component models, calculation methods, Network model: stochastic networks, series and parallel connections, minimum cut sets, reliability costs

- **UNIT COMMITMENT AND ABT** **(03 Hours)**
- Unit commitment and ABT in deregulated scenario

Total Hours: 42

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 Systems) Semester-I	L	T	P	C
EL627: AUTOMATION AND INSTRUMENTATION FOR POWER SYSTEMS33	3	0	0	3

- **INTRODUCTION TO POWER SYSTEM AUTOMATION** **(02 Hours)**
  Historical development of power system automation, Fundamentals of electrical protection, development of protective relays, numeric (microprocessor based relays).

- **SUBSTATION AUTOMATION SUBSYSTEMS** **(02 Hours)**
  Protective relays, Remote terminal unit, PLC,SCADA and other intelligent devices.

- **POWER SYSTEM AUTOMATION ARCHITECHURES** **(03 Hours)**
  Types of power system automation architecture, Automation of HV substations, automation of MV substations.

- **RECENT TRENDS IN MEASUREMENT OF ELECTRICAL QUANTITIES** **(10 Hours)**
  Current Voltage measurement with instrument transformers, Digital techniques of measurement of voltage, current, power, energy and , power factor Hall effect sensors, Measurement of THD and harmonics.

- **INTORDUCTION TO PLC** **(03 Hours)**
  PLC architecture, modular and micro PLCs, PLC Hardware, Input-Output modules, CPU Module, PLC scan cycle.

- **INTRODUCTION TO PLC PROGRAMMING** **(09 Hours)**
  Introduction to ladder diagrams, hard wired relay logic, ladder logic symbols Boolean logic programming examples, timers, counters, Registers, Programming of arithmetic instructions, programming of analog inputs and outputs.

- **SCADA SYSTEMS** **(03 Hours)**
  Requirement and background, SCADA programming, SCADA master station.

- **COMMUNICATION IN POWER SYSTEM AUTOMATION** **(04 Hours)**
  Basics of data communication, The OSI model, Media access control principles, CSMA/CD Ethernet MAC, Full duplex Ethernet, Communication protocols, Mode bus and Mode bus TCP/IP, Profibus, TCP/IP, DNP3.

- **IEC 61850 STANDARD FOR SUBSTATION AUTOMATION** **(06 Hours)**
  Logical Nodes (LN), Logical Device (LD), Intelligent Electronic Devices(IEDs), Process level functions, Bay level functions, Station Level Functions**,** Station Bus and Process Bus.

Total Hours: 42

BOOKS RECOMMENDED:

1. Helfrick – Cooper, Modern electric instrumentation and measurement technique, PHI 1994.
2. T.S. Rathore, Digital measurement techniques, Narosa publishing House, 1996.
3. John Webb, Ronald Reis - Programmable Logic Controllers , PHI, 2003.
4. Klaus-Peter and Others – Substation Automation Handbook, Utility Automation Consulting Lohmann, ISBN 3-85758-951-5.

M.Tech (Power Systems) Semester-I	L	T	P	C
EL629: MICROCONTROLLER BASED SYSTEM DESIGN	**3**	**0**	**0**	**3**

- **REVIEW OF 8051 ARCHITECTURE** **(06 Hours)**

  8051 Hardware Architecture, interrupt system, I/O Ports, Timers, Serial Communication with UART,

- **INTRODUCTION TO EMBEDDED 'C' PROGRAMMING** **(04 Hours)**

  Variables and constants, storage classes, enumerations and definitions, I/O operations, control statements, functions, pointers and arrays, structure and unions, interrupt service routines.

- **Advancements in 8051 ARCHITECTURE (Hardware Concept & Programming)** **(10 Hours)**

  SPI & I2C serial Communication interface, programmable counter array (PCA) and different modes of operation, Interfacing of Parallel ADC & DAC, watchdog timers.

- **INTRODUCTION TO CIP-51 CONTROLLER ARCHITECTURE** **(04 Hours)**

  Memory Map, Instruction Pipeline, MAC Unit, PLL & Clock System, On Chip Peripherals

- **HARDWARE CONCEPT AND PROGRAMMING OF CIP-51 PERIPHERALS** **(14 Hours)**

  Timers / Counters , PCA Timer in different modes, On Chip ADC and DAC sab Systems, UART, MAC Unit, On chip PLL

- **INTRODUCTION to 32-bit Microcontroller (ARM CORTEX M Series)** **(04 Hours)**

  CM3 core architecture, BUS Matrix, AHB & APB Buses, Memory Map, Interrupt Controller, Study of on Chip Peripherals

Total Hours: 42

BOOKS RECOMMENDED:

1. Kenneth J. Ayala, "The 8051 Microcontroller", Penram International 3rd edition, 1996.
2. M. Mazidi and others, "The 8051 Microcontroller and Embedded Systems", PRENTICE Hall Of India, 3rd Edition, 2001.
3. Datasheet of SILABS C8051F12X
4. Subrata Ghoshal, "Embedded systems and Robots", Cengage Learning publication, 2001.
5. Barnett, O'cull, Cox, "Embedded C Programming and the Microchip PIC", Cengage Learning publication.
   User Manual LPC 17XX

M.Tech (Power Systems) Semester-I	L	T	P	C
EL631: DIGITAL SIGNAL PROCESSING	3	0	0	3

- **INTRODUCTION** **(06 Hours)**

  Signals, systems and signal processing, classification of signal concept of discrete time signals, sampling of analog signal and sampling theorem, anatomy of digital filter.

- **DISCRETE TIME SIGNALS AND SYSTEMS** **(10 Hours)**

  Classification , analysis of discrete time signals and systems, implementation of discrete time systems, correlation of discrete time signals, z transform and its application to the analysis of linear time invariant systems.

- **DISCRETE TIME FOURIER, DISCRETE FOURIER AND FAST FOURIER TRANSFORMS** **(10 Hours)**

  Frequency domain sampling, Definition and properties of DTFT and DFT and their inverses, efficient computation of DFT : FFT algorithms: DIT and DIF, Quantization effects in the computation of the DFT.

- **DIGITAL FILTERS** **(10 Hours)**

  Structures of FIR and IIR filters, design of FIR filters using windows; Optimum approximations of FIR filters using Parks- McClellan algorithm, Analog low pass filter design. Anti-Aliasing filter design. Design of IIR filters from analog filters by bilinear transformations; impulse invariance method.

- **APPLICATIONS OF DSP** **(06 Hours)**

  Applications of DSP to power system/power electronics/Instrumentation.

Total Hours: 42

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. Rabiner-Gold, Theory & application of digital signal processing, PHI, 1992.

M.Tech (Power Systems) Semester-I	L	T	P	C
EL633: OPTIMIZATION METHODS	3	0	0	3

- **INTRODUCTION** **(03 Hours)**

  Historical Development, Engineering application of Optimization, Formulation of design problems, Classification of optimization problems.

- **LINEAR PROGRAMMING** **(12 Hours)**

  Theorems 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 VARIABLE OPTIMIZATION** **(05 Hours)**

  Classical Methods, Bracketing Methods, Region Elimination Method, Gradient Based methods: Newton-Raphson Method, Bisection Method, Secant Method

- **MULTIVARIABLE OPTIMIZATION** **(08 Hours)**

  Classical Methods, Direct Search Methods, Gradient Based Methods: Steepest Descent Method, Conjugate Gradient Method, Quasi-Newton Method, Variable Metric Method

- **CONSTRAINED OPTIMIZATION TECHNIQUES** **(08 Hours)**

  Characteristics of a constrained problem, Variable Elimination Method, Lagrange Multiplier, Kuhn-Tucker Conditions, Frank-Wolfe Method, Cutting plane Method, penalty function Methods,

- **ADVANCED OPTIMIZATION TECHNIQUES** **(6 Hours)**

  Introduction to Multi objective Optimization, Genetic Algorithm and other Nontraditional Optimization Algorithms.

Total Hours: 42 Hours

BOOKS RECOMMENDED:

1. S. S. Rao, 'Engineering "Optimization theory and applications", Fourth Edition, John Wiley ans 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.Sherali and C.Shetty , "Nonlinear Programming, Theory and Algorithms", John Wiley and Sons, New York, 1993
4. A. Ravindran, K.M.Ragsdell, G.V. Reklaitis,'Engineering Optimization Methods and Applications', Wiley India Pvt. Ltd., 2006.
5. Rangrajan K. Sundaram," A First Course in Optimization Theory", Cambridge University Press, 1996
6. Dimitri P. Bertsekas," Nonlinear Programming", Athena Scientific, Second Edition,1999

M. Tech. (Power systems), Semester – I	L	T	P	C
EL635: LINEAR ALGEBRA	3	0	0	3

- **FINITE-DIMENSIONAL LINEAR SPACE** **(16 hours)**

  vector spaces, basis, linear operator, matrix representation of the operator with respect to a basis, range of the operator, rank of the operator, null space, nullity, rank-nullity Theorem, solutions of a set of linear equations, generalized inverses, inner product space, Cauchy-Swartz inequality, Hölder inequailty, triangular inequality, Minkowski inequality, orthogonal basis, orthonomal basis, orthogonal projection Lemma, Gram-Schmidt orthogonalisation.

- **THE THEORY OF MATRICES AND JORDAN FORM** **(10 hours)**

  the concept of eigen value and eigen vectors, eigen space, characteristic polynomial, minimal polynomial, Caley-Hamilton Theorem, T conductor of a vector α into a subspace w, diagonalazable and triangulable properties of the operator T, computation of the matrix exponential e^{At}, invariant subspaces, Jordan basis, Jordan chain, Jordan subspaces, matrix representation of the operator with respect to the Jordan basis, similarity transformation, algebraic multiplicity, geometric multiplicity, Segre characteristics.

- **LTI SYSTEMS AND RELATED TOPICS** **(16 hours)**

  Continuous-time linear homogeneous equations with constant coefficients, linear non-homogeneous equations with constant coefficients, discrete-time linear homogeneous equation with constant coefficients, discrete-time linear non-homogeneous equations with constant coefficients, concept of transfer function, stabilty analysis of LTI systems using the concept of characteristic polynomial, Jury stability criteria, Schur-Cohn test, the concept of linear stochastic differential systems, stationary processes, the basic concept of the Fourier transform, the convolution Theorems associated with the Fourier transform, autocorrelation function, cross correlation function, power spectral density, Wiener-Khinchin relationship, characteristic function, the relation between output-input correlation functions.

Total Hours: 42

BOOKS RECOMMENDED:

1. Kenneth Haffman and Ray Kunze, *Linear algebra*, Prentice Hall Publications.
2. Peter Lancaster and Miron Tismenetsky Timteski, *The Theory of Matrices*: *with Applications*, second edition, Academic Press, London, 1985.
3. C Radhakrishna Rao, *Linear Statistical Inferences and Its Applications*, John Wiley and Sons, the United States of America, 1973.
4. A Papoulis, *Probability, Random Varaibles, and Stochastic Processes*, McGraw-Hill International Editions: New York, 1991.

M.Tech. (Power Systems), Semester – II	L	T	P	C
EL620: POWER SYSTEM DYNAMICS AND CONTROL	3	0	2	4

- **BASIC CONCEPTS** **(04 Hours)**

  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 Hours)**

  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 Hours)**

  Excitation System Modeling, Standard Block Diagram, System Representation by State Equations

- **DYNAMICS OF A SYNCHRONOUS GENERATOR CONNECTED TO INFINITE BUS:** **(06 Hours)**

  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 Hours)**

  Small Signal Analysis, Application of Routh-Hurwitz Criterion, Small Signal Model

- **APPLICATION OF of POWER SYSTEM STABILIZERS** **(05 Hours)**

  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** **(06 Hours)**

  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** **(08 Hours)**

  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: 42 Hours

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 Sons, 2002.

M.Tech. (power systems), Semester – II	L	T	P	C
EI622 : HIGH VOLTAGE ENGINEERING AND EHV AC TRANSMISSION	3	1	2	5

- **GENERATION OF HIGH VOLTAGES** **(10 Hours)**

Generation of High DC Voltages : Half Wave and full wave circuits –Ripple voltages in HW and FW rectifiers. Voltage doubler circuits – Simple voltage doubler and cascade voltage doubler. Voltage multiplier circuits – 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** **(03 Hours)**

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

- **DESIGN, PLANNING AND LAYOUT OF HV LABORATORY** **(03 Hours)**

Test Facilities, Activities & Studies in HV lab, Classification of hv lab, Size & rating of hv lab, grounding of impulse testing laboratories.

- **HV TESTING OF ELECTRICAL APPRATUS** **(08 Hours)**

Non-destructive testing of dielectric materials – measurement dielectric constant and loss factor. Partial Discharge Measurement, Testing of Insulators, Bushings, Isolators, Circuit breakers, Cables, Transformers, Surge diverters, RI Measurement. Condition monitoring of Electrical apparatus.

- **INTRODUCTION TO EHV AC TRANSMISSION** **(02 Hours)**

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** **(03 Hours)**

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** **(05 Hours)**

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** **(05 Hours)**

Coronal 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.

- **DESIGN OF EHV LINES** **(03 Hours)**

Design factors under steady state, Line insulation design based upon transient over voltages.

Total Hours: 42 Hours

BOOKS RECOMMENDED:

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,2002.
4. EPRI, Palo Alto, “Transmission line reference book 345 KV & above”.

M.Tech. (Power Systems), Semester – II	L	T	P	C
EL624: RENEWABLE ENERGY SOURCES	**3**	**1**	**0**	**4**

- **BIO ENERGY** **(10 Hours)**

  Introduction to biomass – Biomass conversion technologies – wet process and dry process – Biogas generation – classification of biogas plants – continuous & batch types – The dome and the drum types – Different variations in the drum type – Types of Biogas plants – Floating gas holder – Fixed dome digester – Biogas from plant wastes – Community biogas plants – Materials used for biogas generation – selection of site for biogas plant – Methods of maintaining Biogas generation – starting a biogas plant – Fuel properties of biogas – utilization of biogas – methods of obtaining energy from Biomass Combustion.

- **WIND ENERGY** **(10 Hours)**

  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 STORAGE** **(14 Hours)**

  Introduction – Solar energy storage systems – thermal storage – sensible heat storage – latent heat storage – solar pond – non conductive solar pond – Extraction of Thermal energy – Applications of Solar pond. Solar Energy Applications: solar thermal electric conversion – 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.

- **GEOTHERMAL ENERGY** **(04 Hours)**

  Introduction to Geothermal Energy – fields – Hydro thermal & semi thermal fields – prime movers for Geothermal Energy conversion – classifications- Advantages of Geothermal Energy over other energy forms – Applications of Geothermal Energy at different temperatures - Geothermal Energy in India – prospects.

- **INTRODUCTION TO FUEL CELL** **(04 Hours)**

Total Hours: 42

BOOKS RECOMMENDED:

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 Systems), Semester –II	L	T	P	C
EL626: APPLICATION OF POWER ELECTRONICS IN POWER SYSTEMS	3	0	2	4

- **REACTIVE POWER COMPENSATION** **(08 Hours)**

  Analysis of uncompensated AC line, Passive reactive power compensation, Compensation by a series capacitor connected at the mid point of the line, Effect on Power Transfer capacity, Compensation by STATCOM and SSSC

- **PRINCIPLES OF CONVENTIONAL REACTIVE POWER COMPENSATORS** **(06 Hours)**

  Synchronous condenser, Saturated reactor, Thyristor-controlled reactor (TCR), Thyristor controlled transformer (TCT), Fixed capacitor-Thyristor controlled reactor (FC-TCR), Thyristor switched capacitor (TSC), Thyristor-switched capacitor-thyristor controlled reactor (TSC-TCR)

- **STATIC VAR COMPENSATORS** **(08 Hours)**

  Analysis of SVC, Configuration of SVC, SVC Controller, Modelling of SVC, Voltage regulator Design, Voltage control by the SVC, Advantages of the slope in the SVC Dynamic Characteristic, Influence of the SVC on System Voltage, Design of the SVC Voltage Regulator

- **STATIC SYNCHRONOUS COMPENSATORS (STATCOM)** **(06 Hours)**

  Principle of operation, Analysis of a three phase six pulse STATCOM, Multi-pulse converters, Applications of STATCOM

- **THYRISTOR CONTROLLED SERIES CAPACITOR (TCSC) AND STATIC SYNCHRONOUS SERIES COMPENSATOR (SSSC)** **(08 Hours)**

  Principle of operation, Analysis and control, Modelling, Applications

- **UNIFIED POWER FLOW CONTROLLER (UPFC)** **(04 Hours)**

  Operation of UPFC, Control & Protection, Modelling, Applications of UPFC

- **PHASE SHIFTING TRANSFORMER** (**02 Hours)**

  Principle of operation, Modeling, Applications

Total Hours: 42

BOOKS RECOMMENDED:

1. Mathur R. Mohan & Varma R. K “Thyristor–based FACTS controllers for electrical transmission system”, Wiley Inter-Science, 2002.
2. Padiyar K.R. “FACTS controller in power transmission and distribution”, New Age international, Edition 1st 2007.
3. N.G. Hingorani , “Understanding FACTS”, IEEE Press 2001.
4. Acha E., Agelidis V.G.,Anaya-Lara O., T.J.E. Miller, “Power Electronics Control in Electrical System”, Newnes Power Engineering Series,2002.
5. Vijay K. Sood, "HVDC and FACTS Controllers: Applications of Static Converters in Power Systems", Springer; 1 edition, 2004.
6. Miller,T.J.E,” Reactive Power Control in Electric Systems”, John Wiely, 1982.

M.Tech. (Power Systems), Semester – II	L	T	P	C
EL628: ELECTRICAL DRIVES	3	0	0	3

- **FUNDAMENTALS OF ELECTRIC DRIVES** **(08 Hours)**

  Introduction, Choice of Electrical Drives, Dynamics of Electrical Drives, Concept of Multi-quadrant operation, Components of load torques, Selection of motor power rating, Speed torque, speed control, Starting, Braking.

- **DC DRIVES** **(08 Hours)**

  Modeling, Rectifier fed DC drive, Chopper controlled DC drives, Close loop control of DC drive. Analysis of steady state and dynamic operation.

- **INDUCTION MOTOR DRIVES** **(08 Hours)**

  Introduction, Review of three phase I.M. analysis and performance, Analysis of I.M. fed from Non-sinusoidal supply voltage, Stator voltage control, V/f controlled induction motors, Slip power recovery, field oriented control, direct torque and flux control, CSI fed induction motor drives, Applications.

- **SYNCHRONOUS MOTOR DRIVES** **(10 Hours)**

  Introduction, Sinusoidal SPM machine drives, synchronous reluctance machine drives, Trapezoidal SPM machine drive, wound field synchronous motor drive, Load-commutated Synchronous Motor Drives, Model of PMSM, Vector controlled PMSM drive, UPF control, torque angle control, optimum torque per ampere control.

Total Hours: 42

BOOKS RECOMMENDED:

1. P. C. Krause, Oreg Wasynczuk, Scott D. Sudhoff P.C.Krause, Oreg Wasynczuk, Scott D. Sudhoff “Analysis of Electric Machinery and drive systems” , IEEE Press, 2002.
2. P. S. Bhimbra, “Generalised Theory of Electrical Machines “, Khanna Publications.
3. G. K. Dubey, “Fundamentals of Electrical Drives” Narosa, 2001.
4. Dubey .G.K. "Power semiconductor controlled Drives", Prentice Hall international, New Jersey, 1989.
5. R. Krishnan, “Electric motor drives Modeling, Analysis and Control” PHI-India, 2005.
6. Dewan, S. Slemon B., Straughen, A. G.R., "Power Semiconductor drives", John Wiley and Sons, NewYork 1984.

M.Tech. (Power Systems), Semester – II	L	T	P	C
EL630: HIGH VOLTAGE DC TRANSMISSION	3	0	0	3

- **INTRODUCTION** **(06 Hours)**

  Introduction to AC and DC Transmission - application of DC Transmission - description of DC transmission - DC system components and their functions - modern trends in DC Transmission.

- **CONVERTER** **(10 Hours)**

  Pulse Number - Converter configuration - analysis of Graetz circuit - converter bridge characteristics - characteristics of 12 Pulse converters.

- **HVDC CONTROLLERS** **(10 Hours)**

  General principle of DC link control - converter control characteristics - system control hierarchy - firing angle control - current and extinction angle control - Dc link power control - high level controllers.

- **FILTERS** **(08 Hours)**

  Introduction to harmonics - generation of harmonics - design of AC filters - DC filters - carrier frequency and RI noise.

- **PROTECTION** **(08 Hours)**

  Basics of protection - DC reactors - voltage and current oscillations - circuit breakers - over voltage protection - switching surges - lightning surges - lightning arresters for DC systems.

Total Hours: 42

BOOKS RECOMMENDED:

1. Kimbark, "Direct Current Transmission - Vol. I", John Wiley and Sons Inc., New York, 1971.
2. Padiyar. K. R., "HVDC Power Transmission Systems", Wiley Eastern Limited, New Delhi, 2000.
3. Arrillaga. J, "High Voltage Direct Current Transmission", Peter Peregrines, London, 1983.
4. Vijay K. Sood, "HVDC and FACTS Controllers: Applications of Static Converters in Power Systems", Springer; 1 edition, 2004.
5. Chan-Ki Kim, Vijay K. Sood, Gil-Soo Jang, Seong-Joo Lim, and Seok-Jin Lee, "HVDC Transmission: Power Conversions Applications in Power Systems", Wiley, illustrated edition, 2009.

M.Tech. (Power Systems), Semester – II	L	T	P	C
EL632: MODERN CONTROL SYSTEMS	3	0	0	3

- **NONLINEAR CONTROL SYSTEM** **(10 Hours)**

  Introduction to nonlinear systems , describing function analysis, stability of the equilibrium point in Lyapunov sense, asymptotic stability of the equilibrium point, and limit cycles, qualitative analysis of the non-linear autonomous and non-autonomous systems, phase-plane analysis of linear control systems, phase-plane analysis of' non-linear control systems, minimum time trajectory, optimum switching curve.

- **OPTIMAL CONTROL SYSTEM** **(10 Hours)**

  Calculus of variation, fixed-end-point problem, free-end-point problem and constrained variation problem, optimal control Problems, the Hamiltonian formulation, a linear regulator problem, Pontryagin's, Minimum time problems.

- **ADAPTIVE CONTROL SYSTEM** **(12 Hours)**

  Model reference adaptive systems, MIT rule, MKY lemma, self tuning regulators, applications of adaptive control in orbiting satellite, autopilot for surface to air missile, robotic manipulators.

- **ESTIMATION THEORY WITH APPLICATION TO CONTROL** **(10 Hours)**

  Random variable, conditional probability density, conditional expectation, auto correlation, cross correlation Power spectrum density, stochastic resonance, linear minimum variance estimators, Wiener-Hopf equation, orthogonal projection, Wiener filter, Kalman filter, stationary Kalman filters, extended Kalman filter, Ricatti equation, Degenerate Ricatti equation.

Total Hours: 42

BOOKS RECOMMENDED:

1. K. Ogata, “Modern Control Engineering”, 3rd Edition, PHI India limited, 2001.
2. Donald E. Kirk, “Optimal Control: an introduction”, Dover Publications, 2006.
3. I. D. landau, “Adaptive Control (communications and control engineering)”, Springer; 1 edition, 1999.
4. A. P. sage and PL Melsa, “Estimation theory with applications to communication and control”, McGraw Hill: New York (1971).
5. A. Papoulis, “Probability, Random variables, Stochastic processes” McGraw-Hill, 3rd edition, 1991.

M.Tech. (Power Systems), Semester – II	L	T	P	C
EL634: POWER SYSTEM TRANSIENTS	3	0	0	3

- **OVERVOLTAGES IN POWER SYSTEMS** **(12 Hours)**

  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** **(12 Hours)**

  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** **(06 Hours)**

  Rod gap, Arcing Horn, Lightning Arresters, Surge Absorber, Insulation Coordination

- **TRANSIENT IN TRANSFORMERS AND ROTATING ELECTRICAL MACHINES** **(12 Hours)**

  High frequency transients and voltage distribution in windings of transformer and rotating electrical machines, Surge impedance

Total Hours: 42 Hours

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 systems), Semester – II	L	T	P	C
EL636 : DISTRIBUTED GENERATION	3	0	0	3

- **DISTRIBUTED GENERATION** **(14 Hours)**

  Principle of renewable energy systems-technical and social implications, Solar energy, Overview of solar energy conversion methods, Solar radiation components-collector-measurements-estimation; Solar water heating-Calculation. Characteristics-power extraction, types of wind machines, dynamics matching, performance of wind generators , wind mills , applications, economics of wind power, Fuel cells types- losses in fuel cell, applications; MHD generators- application of MHD generation, Battery types, Ultracapacitors based energy storage systems, Flywheel, Hydrogen Technologies, Biomass power, Electric Vehicles

- **MICRO GRID** **(8 Hours)**

  Resources evaluation and needs, Dimensioning integration systems, Optimizing integration systems, Integration systems control, Cases of study: multi-generation buildings

- **PROTECTION IN DISTRIBUTED GENERATION** **(10 Hours)**

  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, Supply guarantee issues

- **PLANNING & OPERATION OF DISTRIBUTED GENERATION** **(10 Hours)**

  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.

Total Hours: 42

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.

SEMINAR
M.TECH. II (3rd SEMESTER)

- Seminar Work will be on the basis on the new development in the area of power system and allied fields.

DISSERTATION PRELIMINARY
M.TECH. II (3rd SEMESTER)

- Dissertation Work will be on the basis on the new development in the area of power system and allied fields.

DISSERTATION
M.TECH. II (4th SEMESTER)

- Dissertation work will be on the basis on the new development in the area of power system and allied fields.