DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Shahbad Daulatpur, Main Bawana Road, Delhi-42

(Academic-PG)

Scheme for Full Time M. Tech. PSY as per NEP-2020

SEMESTER I					
Code	**Type**	**Cr**	**L-T-P**	**Total Credits**	**Level**
PSY501	Advanced Power System Analysis	4	3-0-2	24	500-599*
PSY505	Power System Dynamics & Stability	4	3-0-2		
PSY507	Power Electronics for Renewable Energy	4	3-1-0		
PSY509	Flexible AC Transmission System	4	3-1-0		
PSY531	Departmental Elective 1	4	3-1-0/3-0-2		
PSY525	Self-Study	2	-		
PSY523	Skill Enhancement Course 1	2	-		
UEC501	Audit Course	0	0-0-2		
SEMESTER II					
Code	**Type**	**Cr**	**L-T-P**	**Total Credits**	**Level**
PSY502	Advanced Power System Protection	4	3-0-2	24	500-599*
PSY504	Power System operation & Control	4	3-0-2		
PSY532	Departmental Elective 2	4	3-1-0/3-0-2		
PSY534	Departmental Elective 3	4	3-1-0/3-0-2		
UCC502	Research Methodology	4	2-0-4		
PSY546/ PSY548	Skill Enhancement Course 2/Industrial Training	4	-		
	NHEQF Level				6.5
SEMESTER III					
Code	**Type**	**Cr**	**L-T-P**	**Total Credits**	**Level**
PSY601	High Voltage Engineering	4	3-0-2	16	600-699*
UEC601	Open Elective 1	4	3-1-0		
PSY603	Minor Project/Research Thesis/Patent	8	0-0-8		
*: Refer Draft UGC Curriculum and Credit Framework for PG Programmes					
SEMESTER IV					
Code	**Type**	**Cr**	**L-T-P**	**Total Credits**	
PSY602	Major Project/Research Thesis/Patent	16	-	16	-
	NHEQF Level				7.0

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Shahbad Daulatpur, Main Bawana Road, Delhi-42

(Academic-PG)

Scheme for Part Time M. Tech. PSY as per NEP-202

SEMESTER I					
Code	**Type**	**Cr**	**L-T-P**	**Total Credits**	**Level**
PSY501	Advanced Power System Analysis	4	3-0-2	12	500-599*
PSY505	Power System Dynamics & Stability	4	3-0-2		
PSY507	Power Electronics for Renewable Energy	4	3-1-0		
SEMESTER II					
	Type	**Cr**	**L-T-P**	**Total Credits**	**Level**
PSY502	Advanced Power System Protection	4	3-0-2	12	500-599*
PSY504	Power System operation & Control	4	3-0-2		
PSY532	Departmental Elective 2	4	3-1-0/3-0-2		
	NHEQF Level				6.5
SEMESTER III					
Code	**Type**	**Cr**	**L-T-P**	**Total Credits**	**Level**
PSY509	Flexible AC Transmission System	4	3-1-0	12	600-699*
PSY531	Departmental Elective 1	4	3-1-0/3-0-2		
PSY525	Self-Study	2	-		
PSY523	Skill Enhancement Course 1	2	-		
UEC501	Audit Course	0	0-0-2		
*: Refer Draft UGC Curriculum and Credit Framework for PG Programmes					
SEMESTER IV					
Code	**Type**	**Cr**	**L-T-P**	**Total Credits**	**Level**
PSY534	Departmental Elective 3	4	3-1-0/3-0-2	12	500-599*
UCC502	Research Methodology	4	2-0-4		
PSY546/ PSY548	Skill Enhancement Course 2/Industrial Training	4	-		
	NHEQF Level				6.5
SEMESTER V					
Code	**Type**	**Cr**	**L-T-P**	**Total Credits**	**Level**
PSY601	High Voltage Engineering	4	3-0-2	16	600-699*
UEC601	Open Elective 1	4	3-1-0		
PSY603	Minor Project/Research Thesis/Patent	8	0-0-8		
SEMESTER VI					
Code	**Type**	**Cr**	**L-T-P**	**Total Credits**	**Level**
PSY602	Major Project/Research Thesis/Patent	16	-	16	-
	NHEQF Level				7.0

Departmental Electives 1

Advanced Control System
Power Quality
Smart Grid & Microgrid
Power System Reliability
Soft computing (same as C&I)
SCADA & Energy Management (same as C&I)

Departmental Electives 2

PMU & Wide area Monitoring system
HVDC Transmission
EHVAC Transmission
Power System Transients
Grid Integration of Renewable Energy System
Energy Storage System (same as PES)

Departmental Electives 3

Optimization Techniques
Forecasting Techniques
Electricity Market Regulations & Trading
Power System Planning
Substation Automation

SYLLABUS

M.TECH POWER SYSTEM

SEMESTER I

Advanced Power System Analysis

Introduction and design considerations of EHV AC systems. Analysis of long transmission lines. Modelling of power system components. Formation of power network matrices. Power Flow studies.
N-R method decoupled and fast decoupled methods. Programming considerations for large systems – sparse matrix techniques. Economic Load Dispatch, Optimal Power Flow, Fault Studies - Symmetrical and unsymmetrical faults using matrix methods. Stability Studies – Transient and dynamic stability analysis of single machine connected to infinite bus and multi-machine systems.

Suggested Reading:

1. Stagg G. & El Abiad, A.H., Computer Methods in Power System Analysis, McGraw Hill.
2. Anderson P.M., Analysis of Faulted Power Systems, IEEE Press.
3. Arrillaga J., Arnold C.P., Computer Modelling of Electrical Power Systems, John Wiley.
4. Wood & Wollenberg, Power Generation, Operation and Control, John Wiley.
5. Elgerd, O.I., Electric Energy Systems Theory, TMH.

Power System Dynamics and Stability

Basis concepts of dynamical systems, Modelling of power system components for stability studies, generator, excitation systems, prime mover controller and associated systems, induction machines and composite loads, transmission lines. Analysis of single machine and multi machine systems. Small signal stability, low frequency oscillations, damping and synchronizing torque analysis, eigenvalue analysis. Power System Stabilizers. SSR and torsional oscillations-analysis and countermeasures.

Suggested Reading:

1. Power System Stability by Kimbark Vol. I&II, III – 1968, Dover Publication Inc, New York 1968.
2. Power System control and stability, P.M. Anderson & A.A. Fouad, Galgotia Publications New Delhi – 110060, 1981, 1st edition.
3. Power System Dynamics Stability and Control by K.R.Padiyar, Second edition B.S.Publications 2002.
4. Power System Analysis by John J.Graniger William D.Stevenson. JR. – Tata McGraw Hill Publications.
5. Kundur, P., “Power System Control and Stability”, McGraw Hill.
6. Pai, M.A., and Sauer. P., “Power System Dynamics & Stability”, Prentice Hall.

Power Electronics for Renewable energy

Basics of Power Converters: AC to DC converters (1phase, 3phase), DC to AC converters(1phase, 3phase), Multilevel DC to AC converters , Types of DC-DC converters-non-isolated and isolated, Basic control principles in power electronics, modulation methods and control techniques , DC-DC converter design and modelling of buck, boost and buck boost DC-DC converter, Grid synchronization: SRF-PLL and DSOGI-PLL, Solar PV Systems: Solar PV characteristics, Grid requirement for PV, Power electronic converters used for solar PV, Control techniques, MPPT, Grid connected and Islanding mode, Wind Energy Conversion: Wind Turbine characteristics, Grid requirement for Wind, DFIG for wind generators and Control

Suggested Reading:

1. Frede Blaabjerg, “Control of Power Electronic Converters and Systems”, Academic Press, 2018
2. Remus Teodorescu, Marco Liserre, Pedro Rodriguez, “Grid Converters for Photovoltaic and Wind Power Systems” Wiley-IEEE Press, January 2011.
3. Suleiman M. Sharkh, Mohammad A. Abu-Sara, Georgios I. Orfanoudakis, Babar Hussain, “Power Electronic Converters for Microgrids” Wiley-IEEE Press, April 2014.

4. Fang Lin Luo, Hong Ye, “Advanced DC/AC Inverters: Applications in Renewable Energy” CRC Press.

Flexible AC Transmission Systems

Introduction, principles of reactive power control and transmission line compensation, series and shunt reactive power compensation, concept of Flexible AC Transmission systems (FACTS), Static Var Compensator (SVC), thyristor controlled reactor, thyristor switched capacitor, thyristor controlled series capacitor, static synchronous compensator, static synchronous series compensator, thyristor controlled phase angle regulator and unified power flow controller. Modeling and analysis of SVC, STATCOM, TCSC, SSSC, UPFC and IPFC, use of FACTS controllers in system control and protection. Harmonic and filters, simulation and study of FACTS Controllers under dynamic conditions.

Suggested reading:

1. Miller, T.J.E., “Reactive Power Control in Electric Systems”, John Wiley.
2. Hingorani, N.G., and Gyugyi, L., “Understanding FACTS”, IEEE Press.
3. E. Acha, V.G. Agelidis, “Power Electronic control in Electrical Systems”, Newnes, Butterworth, Elsevier.
4. R.M. MATHUR, R.K. VARMA, " Thyristor based FACTS controller for Eletctrical Transmission systems, John Wiley.

Departmental Elective I:

To be chosen from the Elective I list

Self-Study:

Topic related to Project / Research which shall be approved by HOD/Program Coordinator/Supervisor

Skill Enhancement Course I:

Course on Professional software/ Industrial Standards & Protocol/ PCB design/ skill course approved by HOD/Program Coordinator/Supervisor

SEMESTER II

Advanced Power System Protection

Review of relay characteristics and operating equations with respect to static comparators. CTs, PTs and mixing transformers, effect of CT saturation on relay operation. Basic construction of static relays, input output devices, D.C. supplies and associated elements; time delay circuits. Static comparators: Different types of two input amplitude and phase comparators; theory and operation, effect of offset and remedy. Introduction of multi input comparators and characteristics. Transient over voltages and their suppression; Different type of relays: static, digital and computer aided relaying. Bus bar arrangements; High current bus bars and design consideration. Review of arc formation, properties and characteristics; interruption of current in circuit breakers; high resistance and low resistance theories of interruption; Effect on circuit breaker performance under different conditions in power system operation; Circuit breaker ratings. Study and operation of air blast, SF6, vacuum and D.C. circuit breakers. Selection and design considerations, Circuit breaker testing methods as per standard.

Suggested Reading:

1. R. van C. Warrington, “Protective Relays Their Theories and Practice”. Volume II, Third Edition, John Wiley & Sons, Inc, New Yark.
2. Ravindranath and M. Chander,“Power System Protection and Switchgear”, First Edition, New Age International (P) Limited
3. Ram And D. N. Vishwakarma, “Power System Protection And Switchgear”, Ninth Reprint, Tata McGraw-Hill Publishing Company
4. R. T. Lythall, “The J&P Switchgear Book”. Seventh Edition, Newnes-Butterworth.
5. Stan Stewart, “Distribution Switchgear”, The Institution of Electrical Engineers, London.
6. Power System Relaying, Stanley H Horowitz and A G Phadke, Willey, 2014.

Power system operation and control

General characteristics of modern power systems, evolution, structure, power system control, operating states of a power system and control strategies, economic load dispatch, price based unit commitment problem. Concept of reactive power, reactive power flow analysis, active power and frequency control, real power balance and its effect on system frequency; Static VAR systems, types of SVC, fundamental frequency performance of SVC, application of SVC. Automatic generation control 416 (AGC), generation control loops, load frequency control, AGC with economic dispatch performance measures, large signal, small signal, control and protective functions, ac and dc regulators, design of robust controllers in power systems. Division of power system into control areas, load-frequency control of single area and two area system - optimum control criterion, two area and multi-areas power system with and without integral control, SCADA systems and its applications in power networks, supervisory control, supervisory master stations, remote terminal units, communication links.

Suggested Reading:

1. Elgerd O.I, "Electric Energy System Theory – an Introduction", Tata McGraw Hill, New Delhi.
2. Kundur. P., "Power System Stability and Control", EPRI Publications, California
3. Allen J. Wood and Bruce. F. Wollenberg, "Power Generation Operation and Control', John Wiley & sons, New York.
4. Mahalanabis A.K., Kothari. D.P. and Ahson. S.I., "Computer Aided Power System Analysis and Control", Tata McGraw Hill publishing Ltd.
5. Vaibhav Donde, M.A. Pai & Ian A. Hiskens – "Simulation & Optimization in an AGC system after deregulation", IEEE transactions on Power Systems
6. L.K.Kirchmeyer, "Economic Control of Interconnected systems", Wiley
7. R.N. Dhar, "Computer Aided power system operation and analysis", TMH

Departmental Elective II:

To be chosen from the Elective II list

Research Methodology:

Common University syllabus

Skill Enhancement Course II/ Industrial Training

Course on Professional software/ Industrial Standards & Protocol/ PCB design/ skill course approved by HOD/Program Coordinator/Supervisor or

Industrial Training approved by HOD/Program Coordinator/Supervisor

SEMESTER III

High Voltage Engineering

Breakdown in Gases, Breakdown in Uniform field, Townsend's mechanisms, Streamer Theory, Paschen's Law, breakdown in electronegative gases. Breakdown of gases in non-uniform field: effect of space charge, corona for positive and negative polarities. Breakdown phenomena under AC voltage and impulse voltage. Breakdown in Liquids: Classification of liquids, breakdown in pure liquids, breakdown in commercial liquids. Breakdown in Solids: Intrinsic breakdown, electromechanical breakdown, Thermal breakdown, Treeing and tracking, breakdown in Composite Insulators. Generation of high direct voltages: Rectifier circuits, voltage doubler and multiplier circuits, cascade circuits; Cascaded transformers, series resonant circuits; Characteristics of impulse and switching surge voltage, analysis of single stage impulse generator circuit, multi-stage impulse generators, constructional features of multi-stage impulse generators. Generation of Switching surges. High Voltage Testing of Power System Equipments. Over-voltages in Power Systems and Insulation Coordination.

Suggested reading:

1. Naidu, M.S. and Kamaraju, V. , "High Voltage Engineering", TMH

2. Wadhwa, C.L., “High Voltage Engineering”, Wiley Eastern
3. Westinghouse Transmission & Distribution Reference Book, IBH
4. Kuffel & Zaengl, “High Voltage Engineering”, Pergamon Press.

Open Elective I:
To be chosen from open elective courses

Minor Project/Research Thesis/Patent
Topic approved by HOD/Program Coordinator/Supervisor

SEMESTER IV

Major Project/Research Thesis/Patent
Topic approved by HOD/Program Coordinator/Supervisor

Departmental Electives I

Advanced Control Systems
Modeling of dynamical systems in continuous time state space and discrete time state space model, Solution of continuous time state equation, Solution of discrete time state equation. General concept of Controllability and Observability, Controllability test for continuous time and discrete time system, Observability test for continuous time and discrete time system, Stabilizabilty and Detectability definition and tests, loss of Controllability and Observability due to sampling, Controllable and Observable canonical forms. Nonlinear Models, Equilibrium points, Linearization of Nonlinear models, Separable Nonlinearities, Describing function analysis, Phase plane analysis of nonlinear systems, Bang-Bang control system, feedback linearization. Stability concept, stability definition in the sense of Lyapunov, Lyapunov stability theorem, Lyapunov instability theorem, direct method of Lyapunov for continuous time and discrete time systems, Lyapunov function for nonlinear systems. Pole placement technique, Ackerman’s approach and Linear quadratic regulator for continuous time and discrete time systems, sliding mode control, H-infinity control, full order and reduced order observer design.
Suggested Reading:
1. J.P. Hespanha, ‘’ Linear Systems Theory”, Second Edition, Princeton University Press, 2018.
2. Hostetter G. H., Savant, and Stefani, Design of Feedback Control Systems, Oxford University Press ,2001.
3. Kailath Thomas, Linear Systems, Prentice Hall ,1996.
4. Khalil, H., Nonlinear Systems, 3nd Ed., Macmillan, 2002
5. Slotine, J.J., and Li. W.P., Applied Nonlinear Control, Prentice-Hall, 1991.
6. Vidyasagar M., Nonlinear Systems Analysis, Prentice Hall, 2nd Edition ,1992

Power Quality
Classification of Power Quality issues, characterization, Power acceptability curves – Power quality problems: Poor load power factor, Non-linear and unbalanced loads, DC offset, Notching, Disturbance, flicker, transients, voltage fluctuations, sags/swells/unbalance, Power Quality Indices, recommended practices, Influence of Non-Sinusoidal Conditions: Transmission and Distribution, Resonance, Shunt capacitors, Transformers, Inrush currents, Electric Machines, Ground systems. Voltage, Current, Power and Energy measurements, power factor measurement, Analysis in the periodic steady state, Time domain method, Frequency domain methods, IRPT, SRF Theory, instantaneous symmetrical components, Analysis of unbalanced systems, Analysis and reduction of voltage sag, Harmonics & Voltage Fluctuations: Sources and Effects, flicker, impulses, occurrence and causes of voltage unbalance, symmetrical

components. Utility- Customer Interface-Harmonic filter, Load compensation and voltage regulation using DSTATCOM, Uninterruptible Power Sources, BESS, DVR, UPQC.

Suggested reading:

1. A. Ghosh and G. Ledwich, "Power Quality Enhancement Using Custom Power Devices", Kluwer Academic.
2. G.T. Heydt. "Electric Power Quality", Stars in a Circle Publications (2nd Edition).
3. J. Arrillaga, N.R. Watson, S. Chen, Power System Quality Assessment, John Wiley & sons, New York.
4. Math H.J. Bollen, Understanding Power quality problems, IEEE Press, New York.
5. E. Acha, Manuel Madrigal, Power system Harmonics, John Wiley & sons, New York.
6. Moreno – Murioz (Ed), Power Quality (Mitigation Technologies in Distribution Environment Springer, 07.
7. Bhim Singh, Ambrish Chandra, Kamal Al-Haddad,"Power Quality Problems and Mitigation Techniques", John Wiley & Sons Ltd. 2015.

Smart Grid & Microgrid

Introduction: Structure and Fundamental Problems of Electrical Power Systems, Principles of Electrical Power Control, Power Flow Control, Distributed Generation and Energy Storage, Benefits to Grids, Damping of System Oscillations, Power Quality Control, Fully Integrated Power System-Smart Grid, Smart Electrical Energy Networks Concept-Microgrids & Picogrids. Microgrid configuration and interconnection, Technical advantages and challenges of Microgrid. Distribution system and operational issues of Microgrid, power quality, Ride through, Grid synchronization. Network management needs of Microgrid, Microsource generation control, Domestic process control, Energy storage, Regulation and load shifting, Microsource controller, Decentralized Operation, Protection co-ordination, Grid Synchronization. PWM Rectifiers, Multilevel Converters, Neutral point Clamped VSC, space vector PWM, Z-source converters, Three level and Four wire inverters with z source, Grid-imposed Frequency VSC system control , D-STATCOM, SSSC, UPFC, Back to Back HVDC Conversion Systems, Bricks-Buses-Software (BBS). SCADA and control of DNO SCADA systems (Centralised & Distributed).

Suggested reading:

1. Mini S. Thomas, John Douglas McDonald, "Power System SCADA and Smart Grids", CRC Press 2015.
2. S. Chowdhary, S. P. Chowdhury and P. Crossley, "Microgrids and Active Distribution Network", IET, 2009
3. R. Strzelecki, G. Benesek, "Power Electronics in Smart Electrical Energy Networks", Springer, 2008
4. Amirnaser Yazdani & Reza Iravani, "Voltage Sourced Converters in Power Systems: Modeling, Control, and Applications", IEEE Press, 2010.
5. Nick Jenkins et al., "Embedded Generation", IET, 2000.

Power System Reliability

Basic probability theory, review of concepts, probability distributions. Markov processes, State Transition Matrix and state Transition Diagram. Definition of Reliability, general reliability function, evaluation of reliability using state enumeration. Tie set and cut set method. Reliability indices from state transition matrix and state transition diagrams. Models for generation system reliability evaluation, loss of load indices, loss of energy indices, frequency and duration methods. Reliability evaluation of two area interconnected system. Conditional probability approach for reliability evaluation of a generation-transmission system. Transmission system reliability evaluation using average interruption rate method and frequency and duration methods. Evaluation of interruption indices for radial distribution systems. Introduction to protective system reliability evaluation.

Suggested reading:

1. Billington, Ringley & Wood, "Power System Reliability Calculation", MIT Press.
2. Endeerny, J, "Reliability Modelling in Power System", John Wiley, NY.

Departmental Electives 2

PMU & Wide area Monitoring system

Synchro phasor technology; Time-synchronized concepts and measurements, synchrophasor application in power system; Global Positioning System (GPS); PMU and it's principle of operation; PMU specifications, selection of locations; Phasor Data Concentrator (PDC); Wide Area Measurement system(WAMS) and monitoring concepts; State estimation (SE) and visulization of state estimators; PMUs for rotor angle stability, voltage stability, fault assessments and oscillation monitoring. Advanced metering infrastructure (AMI) and benefits, AMI System requirements and key components; Automated meter reading (AMR) network topology; TOD metering, Net Metering, Head-end-system; Differences between AMI and AMR; Wireless and wired communications (viz. PLCC,RF, WiFi, Optical fibre communication); Walk-by, drive-by and fixed network methods for data collection, communication flows; communication latency; advanced SCADA.

Suggested Readings:

1. Synchronized Phasor Measurements and Their Applications by Arun G Phadke, James S Thorp, Springer, 2017.
2. Power System Grid Operation Using Synchrophasor Technology, Edited by Nuthalapati, Sarma, Springer, 2019
3. Phasor Measurement Units and Wide Area Monitoring Systems byAntonello Monti , Carlo Muscas, Ferdinanda Ponci , Kindle Edition.
4. PMU Placement in Power System Network: A case Study by Ashish Mishra, Publisher: Lambert, May 2017
5. Power System Stability and Control by P. Kundur, McGraw-Hill, New York, 1994.
6. Application of Time-Synchronized Measurements in Power System Transmission Networks by Mladen Kezunovic, Sakis Meliopoulos, Vaiyhianatham Venkatsubramanian,Vijay Mittal, Springer, 2014.
7. Advanced Metering Infrastructure (AMI) by Gerardus Blokdyk , Third Edition, Nov 2018, Publisher: 5starcooks.
8. The 2018-2023 World Outlook for Advanced Metering Infrastructure (AMI) by Icon Group International, Publisher: ICON Group International, Inc., December, 2017.

HVDC Transmission

DC power transmission technology introduction-comparison of ac and dc transmission –application of dc transmission-description of dc transmission system, planning for hvdc transmission-modern trends in dc transmission analysis of hvdc converter pulse number, choice of converter configuration simplified analysis of graetz circuit-converter bridge characteristics, characteristics of twelve pulse converter – detailed analysis of converters.converter and hvdc system control.general principles of dc link control-converter control characteristics-system control hierarchy –firing angle control-current and extinction angle control-starting and stopping of dc link power control –higher level controllerstelecommunication requirements.harmonics and filters. introduction-generation of harmonics-design of ac filters-dc filters-carrier frequency and RI noise. simulations of hvdc systems introduction – system simulation: philosophy and tools-hvdc system simulation-modeling of hvdc systems for digital dynamic simulation. Suggested reading:

1. Padiyar, K.R. "HVDC power transmission systems", Wiley Eastern Limited, New Delhi 1990. First edition.
2. Edward Wilson Kimbark, "Direct Current Transmission", Vol. I, Wiley Interscience, New York, London, Sydney,1971.
3. Arrillaga, J., "High Voltage Direct Current Transmission", Peter Peregrinus, London,1983.

EHVAC Transmission

Introduction Standard transmission Voltages- average values of line parameters- Power handling capacity and line loss, Costs of transmission lines and equipment, Mechanical consideration in line performances.

Corona Effects- Power losses and audible noise, I2R losses and corona loss, Attenuation of travelling waves due to corona loss, Audible noise generation and characteristics, limits of audible noise, Day Night equivalent noise level, Radio Interference, corona pulse generation and properties, Limits for Radio Interference Fields, CIGRE formula, RI excitation function, Measurement of RI, RIV and excitation function, Design of Filter. Electrostatic Field of Ehv Lines – Capacitance of long object, calculations of electrostatic field of AC lines, effect of high electrostatic field on humans, animals and plants, Measurement of electrostatic field, electrostatic induction in unenergized circuit of DC line, Induced voltages in Insulated ground wires, electromagnetic interference. Compensation of Ehv Lines- Series and shunt compensation, problems due to series compensation, Sub-synchronous resonance and remedial measures.

Suggested reading:

1. Begamudre, R.D., EHVAC Transmission Engineering, New Age .
2. Padiyar, K.R., HVDC Power Transmission Systems, Wiley Eastern Ltd.
3. Kimbark, E.W., Direct Current Transmission, John Wiley, U.S.A.
4. Power Engineer's Handbook, Revised and Enlarged 6th Edition TNEB Engineer's Association, October 2002.

Power Systems Transients

Origin and nature of transients and surges. Fundamental concepts of RLC circuit analysis, application of Laplace transform, Simple switching transients, Effect of resistance on LC circuit transients, Abnormal switching transients, Transients in three-phase circuits, Travelling waves on transmission lines, Lightening, Insulation coordination, Overvoltage protection, substation equipment, Lumped and distributed circuit representations. Line energization and de-energization transients, current chopping, short-line faults, trapped charge effects, effect of source, control of transients, Lightening, effect of tower footing resistance, travelling waves, insulation coordination, circuit breakers duty, surge arresters, overvoltage limiting devices, Case studies.

Suggested reading:

1. Allan Greenwood, Electrical Transients in Power Systems, Wiley-Blackwell; 2nd Edition, 1991.
2. Pritindra Chowdhuri, Electromagnetic Transients in Power Systems (High-Voltage Power Transmission), 2nd edition, PHI Learning

Grid Integration of Renewable Energy Systems

Basics of energy, conventional energy sources, renewable energy sources, global and Indian energy scenario, new technologies (hydrogen energy, fuel cells, bio fuels). Solar Energy: Theory of solar cells, solar cell materials, I-V characteristics of solar cell, PV module, PV array, MPPT, PV systems, Stand alone and grid connected PV systems, storage, PV based water pumping, solar radiation and its measurement, flat plate collectors and their materials, applications and performance, solar thermal power plants, limitations. Wind Energy: site selection, power in the wind, impact of tower height, classification of wind turbine and rotors, wind energy extraction, betz'z limit, wind characteristics, performance and limitations of wind energy conversion systems. Biomass, Small Hydro and geothermal energy. Emerging technologies for power generation: Introduction to tidal energy, wave energy, OTEC, principle of working of various types of fuel cells and their working, performance and limitations, Emergence of hydrogen, cost analysis of hydrogen production, hydrogen storage.

Suggested reading:

1. Duffie and Beckmen, Solar Engineering of Thermal Processes, Wiley Publications, 1991.
2. S. P. Sukhatme, Solar Energy, TMH, India, 2008.
3. John Twiden and Tony Weir, Renewable Energy Resources, BSP Publications, 2006.
4. D. P. Kothari, Rakesh Ranjan, Renewable Energy Sources and Emerging Technologies, PHI, India, 2011.
5. C. S. Solanki, Renewable Energy Technologies, A Practical Guide for Beginners, PHI, India, 2012.
6. G. D. Rai, Non Conventional Energy Resources, Dhanpat Rai, India 2006

Departmental Electives 3

SCADA & Energy Management

Concept of Supervisory control & Data Acquisition System, Component and types of SCADA systems, CT, PT, Voltage to current, current to voltage converters, RTUs etc. Supervisory and control functions, man-machine communication, operator console, VDU display and its use, operator dialogues, mimic diagram functions, printing facilities etc. SCADA system structures, system classes, system interactions, performance criteria, software and hardware considerations, data bases, reliability and simulations, technical realizations, local system, communication system, central system, control system supervision & system maintenance. Application functions-real time network modeling, security management, production control and training simulators. Introduction to communication systems, Hotline, PLCC, Mobile, Satellite, Microwave & Optical fibre communications. Transputerised SCADA system, SCADA on embedded FPGA.

Suggested Reading:

1. Krishana Kant, "Computer-based Industrial Control", PHI Publication.
2. Liptak, "Process Control", CRC Publication.
3. Madiseth & Williams, "Digital Signal Processing", CRC Press, IEEE Press.
4. Kissel, "Industrial Electronics", PHI Publication.
5. Mini S. Thomas, John Douglas McDonald, "Power System SCADA and Smart Grids", CRC Press 2015.

Optimization Techniques

Introduction to power system optimization problems and linkages. Optimization basics and solution techniques for convex and nonconvex optimization problems. Static and dynamic optimization techniques. Basic Optimal power flow. Preventive and corrective security constrained optimal power flow, Unit commitment, hydrothermal scheduling, generation, transmission and reactive expansion planning. Optimization with uncertain data, Fuzzy and probabilistic techniques. Generation, transmission and reactive resources planning. Renewable generation integration optimization. Effect of markets and renewable generation in resources planning

Suggested reading:

1. Power generation operation and control, Wood and Woolenberg, WSE
2. Optimization on Power system Operation by Jizhong Zhu Wiley-IEEE Press.
3. S. S. Rao, "Optimization – Theory and Applications", Wiley Eastern Limited, Second Edition, 1984.
4. Kalyanmoy Deb, "Optimization for Engineering Design – Algorithms and Examples", Prentice Hall India
5. D.P. Kothari, "Power System Optimization", TMH.

Forecasting Techniques

Principles of forecasting load, wind and price. Statistical and non-statistical based approaches. AI application for forecasting. Fundamentals of deregulated power market, Market time lines Forecast based decision time frames Principles of forecasting, Taxonomy of forecasting techniques, univariate/ multivariate forecasting, forecasting performance measurement. Statistical forecasting Overview of regression, time series techniques AR, MA, ARMA, ARMAX, ARIMA. Artificial Intelligence Techniques: fundamentals, mathematical modeling Neural Networks Fuzzy Neural Networks Support Vector Machines Hybrid Techniques Load Forecasting: Key issues and challenges. Data and feature selection, analysis and preprocessing, Price forecasting Key issues and challenges, price spikes and volatility analysis, Data selection, analysis and preprocessing, Feature selection, Modeling Model application and validation, Wind speed/power forecasting, ramp forecasting, Key issues and challenges, Uncertainty quantification of forecasts, Confidence/ Prediction Intervals, Future Scope and new challenges in emerging smart grid environment.

Suggested reading:

1. Mohammed Shahidehpour, Hatim Yamin, Zui Li, Market Operations in in Electric Power System: forecasting, scheduling and risk mangement, John Wiley & Sons Ltd, 2002.

2. Rafal Weron, Modelling and Forecasting Electricity Loads and Prices: A statistical approach, John Wiley & Sons Ltd, 2006.
3. G.P. Box and G.M. Jenkins, Time Series Analysis: Forecasting and Control, Holden-Day Inc.
4. S. Makridakis, S.C. Wheelwright, R.J. Hyndman, Forecasting Methods and Applications, Wiley, 1998. 5. Gareth James, Daniela Witten, Trevor Hastie and Robert Tibshirani, "An Introduction to Statistical Learning with Applications in R", Springer, 2013.

Electricity Market Regulations & Trading

Electricity Market Structure, Power Exchanges and its working principle for power trading, Power traders, electricity market clearing methodology, Power Purchase Agreements, Electricity pricing and trading, Demand side Management, Load frequency control, Long term- medium- short term open access in transmission, Grid connectivity, Bilateral contracts, Intraday, day ahead and spot market, Spot and day energy accounting, , Ancillary Services, Electricity Market Operators and Regulators, Regulations of electricity Utilities, T&D loss optimization, Integrating must run generation from RESs.

Suggested reading:

1. Fundamentals of Power System Economics by Daniel Kirschen & Goron Strbac, John Wiley & Sons, Ltd
2. Operation of Restructured Power Systems by Kankar Bhattaccharya, Math H. J.Bollen & Jaap E. Daalder, Kluwer Academic Publishers.
3. Compendium of Regulations, Central Electricity Regulatory Commission, New Delhi.

Power System Planning

Introduction-Power system planning, power system development and growth, power sources, planning tools. Electricity regulations. Electricity Forecasting. Generation Planning. Transmission and distribution network planning. New operation and planning policies. Allocation of reserve. Demand side bidding. Pricing schemes. Competitive electricity markets. Environment effects. Technology and Innovation (Modern Trends).

Suggested reading:

1. Sullivan-"Power System Planning"., McGraw Hill.
2. Pabla, A.S., "Electric Power System Planning", Macmillan, India.

Substation Automation

Substation Automation in Transmission and Distribution Networks – Fundamentals. Data Communication for Power Utilities – Fundamentals. Functions of Substation Automation Systems. Basics of Local Area Networks in digital substations: main components, operation of Ethernet switches, types of traffic, redundancy protocols (RSTP, PRP, HSR). Time synchronization in digital substations: requirements and time synchronization protocols Communication Protocols for Power Utilities: Basic knowledge of IEC 61850: communication models, data model, System Configuration Language (SCL). Configuration for Substation Automation System Digital substations implementation experience: architectures and LAN topologies, Practical example on how to configure merging unit to publish Sampled Values. Testing of digital substations

Suggested reading:

1. Evilio Padilla "Substation automation system – Design and implementation" John Wiley & Sons Ltd, 2016.