M. Tech

IN

POWER SYSTEMS

CURRICULUM AND SYLLABI

(Applicable from 2023 admission onwards)

तमसो मा ज्योतिर्गमय

Department of Electrical Engineering
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
Kozhikode – 673 601, KERALA, INDIA

The Program Educational Objectives (PEOs) of M. Tech in Power Systems

PEO1	Apply enhanced knowledge and skills in the area of power systems so as to excel in various sectors in modern power industry/utility and/ or teaching and/or higher education and / or research.
PEO2	Engage in design of novel products and strategic solutions to real life problems in the areas of power systems that are technically sound, economically feasible and socially acceptable.
PEO3	Exhibit professionalism, keep up ethics in profession and demonstrate communication skills, leadership qualities as well as willingness to work in groups.

Programme Outcomes (POs) of M. Tech in Power Systems

PO1	Ability to independently carry out research /investigation and development work to solve practical problems
PO2	Ability to write and present a substantial technical report/document
PO3	Ability to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
PO4	Ability to utilize the acquired knowledge to take up administrative challenges including the management of projects in the field of Power Systems having multidisciplinary nature with a perspective to maintain lifelong learning process.
PO5	Willingness and ability to upkeep professional ethics and social values while carrying out the responsibilities as a Power System engineer/researcher in devising solutions to real life engineering problems in an independent manner.

CURRICULUM

Total credits for completing the M. Tech programme in Power Systems is 75.

COURSE CATEGORIES AND CREDIT REQUIREMENTS:

The structure of M. Tech programme shall have the following Course Categories:

Sl. No.	Course Category	Minimum Credits
1.	Program Core (PC)	29
2.	Program Electives (PE)	09
3.	Institute Elective (IE)	02
4.	Projects	35

The effort to be put in by the student is indicated in the tables below as follows:
L: Lecture (One unit is of 50-minute duration)
T: Tutorial (One unit is of 50-minute duration)
P: Practical (One unit is of one hour duration)
O: Outside the class effort / self-study (One unit is of one hour duration)

PROGRAMME STRUCTURE

Semester I

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA6003E	Mathematical Methods for Power Engineering	3	0	0	6	3	PC
2.	EE6201E	Computer Methods in Power System Analysis	3	1	0	5	3	PC
3.	EE6202E	Power Converters for Power Systems Application	3	1	0	5	3	PC
4.	EE6203E	Advanced Power System Operation and Control	3	1	0	5	3	PC
5.	EE6204E	Signal Processing for Power Systems	3	1	0	5	3	PC
6.		Programme Elective-1	3	0	0	6	3	PE
7.	EE6291E	Power Systems Computation Lab	0	0	2	1	1	PC
8.		Institute Elective	2	0	0	4	2	IE
		Total	**20**	**4**	**2**	**37**	**21**	

Semester II

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	EE6211E	Power System Stability and Dynamics	3	1	0	5	3	PC
2.	EE6212E	FACTS and HVDC	3	1	0	5	3	PC

3.	EE6213E	Digital Protection of Power systems	3	1	0	5	3	PC
4.	EE6214E	Power System Economics and Deregulation	3	1	0	5	3	PC
5.		Programme Elective -2	3	0	0	6	3	PE
6.		Programme Elective- 3	3	0	0	6	3	PE
7.	EE6292E	Advanced Power Systems Lab	0	0	2	1	1	PC
8.	EE6293E	Project Phase I	0	0	3	3	2	PC
		Total	**18**	**4**	**5**	**36**	**21**	

Semester III

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	EE7291E	Project Phase II*	0	0	6	3	3	PC
2.	EE7292E	Project Phase III	0	0	30	15	15	PC
		Total	**0**	**0**	**36**	**18**	**18**	**--**

**to be completed during Summer*

Semester IV

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	EE7293D	Project Phase IV	0	0	30	15	15	PC
		Total	**0**	**0**	**30**	**15**	**15**	

List of Electives**

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	EE6221E	Power Quality Issues and Remedial Measures	3	0	0	3	6
2.	EE6222E	Wide Area Monitoring and Control of Power Systems	3	0	0	3	6
3.	EE6223E	Power System Reliability	3	0	0	3	6
4.	EE6224E	Parallel and Distributed Processing of Power Systems	3	0	0	3	6
5.	EE6225E	Smart Grid Technologies	3	0	0	3	6
6.	EE6226E	Distributed Generation and Microgrids	3	0	0	3	6
7.	EE6227E	Power System Automation	3	0	0	3	6
8.	EE6228E	Data Analytics in Power Systems	3	0	0	3	6
9.	EE6229E	Power Distribution Systems	3	0	0	3	6
10.	EE6230E	Development and Evaluation of Power Projects	3	0	0	3	6
11.	EE6101E	Systems Theory	3	0	0	3	6

12.	EE6103E	Principles of Measurement Systems	3	0	0	3	6
13.	EE6111E	Digital Control: Theory and Design	3	0	0	3	6
14.	EE6114E	Advanced Sensing Systems and Interfacing Circuits	3	0	0	3	6
15.	EE6302E	Dynamics of Electrical Machines	3	0	0	3	6
16.	EE6322E	Static VAR Controllers and Harmonic Filtering	3	0	0	3	6
17.	EE6424E	Engineering Optimization and Algorithms	3	0	0	3	6
18.	EE6429E	SCADA Systems and Applications	3	0	0	3	6
19.	EE6511E	Extra High Voltage Power Transmission	3	0	0	3	6
20.	EE6514E	Condition monitoring of High Voltage Equipment	3	0	0	3	6

List of Institute Electives

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1	ZZ6001E	Research Methodology	2	0	0	4	2
2	MS6174E	Technical Communication and Writing	2	1	0	3	2
3	IE6001E	Entrepreneurship Development	2	0	0	4	2

*** List of Electives offered in each semester will be announced by the Department. Any other PG level course approved by the senate offered in the Institute can also be credited as Programme Electives with the prior approval of the Programme Coordinator.*

MA6003E MATHEMATICAL METHODS FOR POWER ENGINEERING

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Solve systems of linear equations using the language of matrices.
CO2: Apply the concept of vectors spaces, eigenvalues and eigenvectors.
CO3: Solve unconstrained and constrained nonlinear programming problems.
CO4: Determine approximate solutions to transcendental equations and system of equations using numerical methods.
CO5: Evaluate definite integrals and solve ODEs using numerical methods.

Linear Algebra

System of linear equations: Range space and Null space of a matrix, Rank of a matrix, Existence and uniqueness of solution of the system of linear equations, Dimension of the Solution Space associated with the system of linear equations.
Vector Spaces: Definition of Vector space, Sub spaces, linearly independence and dependence, linear Span, Basis, Dimension. Eigenvalues and Eigenvectors, Properties of eigenvalues and eigenvectors, Similarity matrices, Complex matrices.

Optimization Methods

Unconstrained one-dimensional optimization techniques, Necessary and sufficient conditions, Unrestricted search methods, Fibonacci and Golden section method. Unconstrained n dimensional optimization techniques, Descent methods, Steepest descent, conjugate gradient. Constrained optimization Techniques, Necessary and sufficient conditions, Equality and inequality constraints, Kuhn-Tucker conditions, Gradient projection method.

Numerical Methods

Solution of algebraic and transcendental equations: fixed point iteration method, Newton Raphson method. Solution of linear system of equations, Gauss elimination method, Pivoting, Gauss Jordan method, Iterative methods: Gauss Jacobi, Gauss Seidel and relaxation method, Newton’s method for nonlinear system of equations. Numerical Integration: Trapezoidal and Simpson’s rule, Composite integration methods, Gauss quadrature methods. Numerical Solution of Ordinary Differential Equations: Euler's method, Euler's modified method, Taylor's method, Runge-Kutta method, Multistep methods, Milne's and Adams’ methods, Predictor-Corrector methods.

References:

1. G. Strang, *Introduction to Linear Algebra*, Wellesley MA: Cambridge Press, 2016.
2. D M Simmons, *Nonlinear Programming for Operations Research*, Prentice Hall, 1975.
3. G Mohan and Kusum Deep, *Optimization Techniques*, New age International Publishers,2009.
4. Jain M.K., Iyengar S.R.K., Jain R.K., *Numerical methods for Scientific and Engineering Computation*, 8th edition, New Age International (P) Ltd, 2022.

EE6201E COMPUTER METHODS IN POWER SYSTEM ANALYSIS

Pre-requisites: **NIL**

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Formulate network admittance and impedance matrix for various analyses of power systems

CO2: Execute load flow and short circuit analysis on large scale AC, DC and AC-DC power systems using digital techniques.

CO3: Choose appropriate the load flow methods on various distribution systems

CO4: Develop mathematical models for State Estimation and Contingency analysis

CO5: Assess the various security measures taken for operation of power system

Network Modelling

Network modelling - System Graph. Loop, Cutest and Incidence Matrices - Y Bus Formation – Mutually coupled branches in Y Bus - solution techniques for linear networks -Gaussian Elimination, LU Factorization, Network reduction techniques - Sparsity programming and Optimal Ordering - [ZBUS] Building Algorithm with Mutually coupled branches - digital simulation.

Load Flow Studies and Fault Analysis

Power Flow Analysis: Review of Gauss-Seidel, Newton-Raphson, Decoupled and Fast Decoupled Methods, DC Power Flow, AC-DC Load Flow Analysis, Load Flow under Power Electronic Control

Fault Analysis: Review of Sequence Matrices- Review of Symmetrical and Unsymmetrical Short-Circuit Analysis of Large Power Systems - Phase Shift in Sequence Quantities Due to Transformers - digital simulation

Distribution System Analysis

Load flow analysis of balanced and unbalanced radial distribution system – Load flow analysis of weakly meshed system – Backward/forward sweep - Direct approach - Direct approach for weakly meshed systems - Gauss Implicit Z-matrix Method - Short-circuit analysis: Sequence-components vs. phase-variable - LG, LLG, LLLG, and LL Faults - Weakly meshed system - Applications of distribution system analysis

Power System Security and State Estimation

Power system security - Contingency analysis - adding and removing multiple lines, Analysis of single and multiple contingencies, Contingency Analysis by DC model, System reduction for contingency and fault studies – linear sensitivity factors – AC power flow methods – contingency selection – concentric relaxation – bounding-security constrained optimal power flow-Interior point algorithm-Bus incremental costs.

State estimation – least square and weighted least square estimation methods for linear and non-linear systems. Static state estimation of power systems- injections only and line only algorithms, Treatment of bad data – detection, identification and suppression of bad data.

References:

1. John J. Grainger and William D. Stevenson, *Power System Analysis*, Tata McGraw-Hill, 2003
2. Haadi A. Sadat, *Power System Analysis*, McGraw Hill Co. Ltd., India, 2000.
3. George L. Kusic, *Computer Aided Power System Analysis*, Prentice Hall of India (P) Ltd., New Delhi, 1989.
4. J. Arrilaga, C.P. Arnold, B.J. Harker, *Computer modelling of Electric Power Systems*, Wiley, New York, 1983.
5. A.K. Mahaianabis, D.P. Kothari, S.I. Ahson, Computer Aided Power System Analysis & Control, Tata McGraw Hill, New Delhi, 1988.
6. O.I. Elgard, Electric Energy System Theory: An Introduction, 2nd ed., McGraw Hill, New York, 1982.
7. Mariesa L. Crow, Computational Methods for Electric Power Systems, CRC Press, 2010.
8. Arthur R. Bergen, Vijay Vittal, Power Systems Analysis, Pearson Education, 2009.
9. Allen J. Wood, Bruce Wollenberg and Gerald B. Sheble, '*Power Generation, Operation and Control'*, 3rd Edition. John Wiley and Sons, 2013

EE6202E POWER CONVERTERS FOR POWER SYSTEMS APPLICATION

L	T	P	O	C
3	1	0	5	3

Pre-requisites: **NIL**

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand various VSC Topologies used in various Power System applications of Power Electronic Converters
CO2: Analyse the operation and performance of Two-Level Single phase and Three phase VSCs under various modulation schemes.
CO3: Examine the operation of various multipulse VSCs, three-level NPC VSCs and Cascaded H Bridge VSCs that are routinely employed in Power System Applications.
CO4: Develop the capability to model VSC based systems in *αβ- frame* and *dq-frame* for designing control systems for them.
CO5: Examine different operational and design aspects of controllers for controlling a grid-connected VSC System in *αβ-frame* and *dq-frame* for meeting different control objectives.

Introduction

Power Electronic Converters & Converter Systems: PE Switches – Switch Classification, Switch Characteristics, Classification of Converters – based on commutation process, based on terminal voltage & waveforms, Voltage-Sourced Converters (VSC) – Basic configurations.

Brief Survey of applications of VSCs in Power Systems: STATCOM, DSTATCOM, SSSC, DVR, PQC, UPFC, Active Filters, VSC-based HVDC, Renewable Energy Grid Interface etc., Self-sustained DC Bus versus Active DC Bus in Power System Applications of VSC, Two Basic Strategies for Control of AC Side and DC Side in VSC-Based Power System Applications – Synchronous Link Power Control Principles, Current Regulation in VSCs.

Advanced VSC Configurations: Multimodule VSC, Multipulse VSC, Multilevel VSC, Modular Multilevel VSC *(Ref.1 - Chapter 1)*

Two-Level VSC Modulation Schemes

Single Phase Two-Level VSC: Half-bridge and Full-bridge Single Phase VSC with square wave switching, Harmonic performance, Sinusoidal Pulse Width Modulation (SPWM) for Single Phase half-bridge and full-bridge VSC, Bipolar versus Unipolar SPWM, Harmonics and filtering, Leakage current issue in SPWM Single Phase Inverters fed from Solar Panels, The H5 Inverter for Photovoltaic application *(Ref.5 – Chapter 8, Ref.6 – Chapter 6, Ref.3 – Chapter 2)*

Three Phase Two-Level VSC : 180^0 and 120^0 square wave operation of basic 6-pulse three-phase Inverter - Analysis of waveforms for 180^0 mode with R-Load and RL-Load, Programmed Harmonic Elimination (PHE) for 2-Level three-phase VSC – Implementation of PHE, SPWM for 2-Level three-phase VSC – harmonics; choice of carrier frequency; DC Voltage utilisation; third harmonic injection ; filtering requirements, *(Ref.5 – Chapter 8, Ref.6 – Chapter 6, Ref.2 – Chapter 6, Ref.4 – Chapter 3)*

Space Vector Modulation (SVM) : Motivation for SVM for Three-phase Two-Level VSC, Switching States, Space Vectors, Dwell Time calculation, Modulation Index, Switching Sequence, Spectrum Analysis, Even Harmonic Elimination, Discontinuous SVM *(Ref.2 – Chapter 6)*

Introduction to Current Regulated Two-Level VSC: Application of Current-regulated VSCs in Power Systems – Grid side current regulation in a grid-connected single-phase two-level PWM inverter by hysteresis control – Hysteresis current control in grid-connected three-phase two-level PWM Inverter – Disadvantages of hysteresis current control *(Ref.5 – Chapter 8)*

Advanced VSC Configurations

Multipulse VSCs: Harmonics in 6-pulse VSC, 12-pulse VSC arrangement and magnetic involved, harmonic performance of 12-pulse VSC, 24-pulse VSC arrangement and magnetic involved, harmonic performance of 24-pulse VSC, 48-pulse VSC arrangement and magnetic involved, harmonic performance of 48-pulse VSC, Combining PHE and Multipulsing – motivation, implementation aspects. *(Ref.4 – Chapter 3)*

Diode Clamped Multilevel Inverters: Three Level Single Phase Half Bridge Neutral Point Clamped (NPC) VSC, PWM Scheme for Half Bridge NPC - Harmonic performance, Three Level NPC Three Phase VSC with impressed DC Voltages, NPC VSC with Capacitive DC Side Voltage Divider – Partial DC Side Voltage drift; DC Side Voltage Equalisation; DC Side Currents *(Ref.1 – Chapter 6, Ref.4- Chapter 3, Ref.2 – Chapter 8)*
Space Vector Modulation for NPC VSC *(**Self-study** by using Ref.2 – Chapter 8 Sections 8.3 & 8.4)*

Cascaded H Bridge Inverters: CHB Inverter with equal DC voltages, CHB Inverter with unequal DC voltages, Carrier based PWM Schemes – Phase shifted Multicarrier Modulation; Level shifted Multicarrier Modulation; comparison, Staircase Modulation. *(Ref.2 – Chapter 7)*

Modelling & Control of Grid-Connected VSC

Half-bridge PWM VSC Modelling & Control: Switched Model, Averaged Model, Non-ideal Converter, Averaged Model for Non-ideal Converter, AC Side Control model of Half-bridge converter, Control of Half-bridge converter, Feedforward compensation and its impact, Sinusoidal Command Following *(Ref.1 – Chapters 2&3)*

Space Phasors & Two dimensional Frames : Space Phasor – definition; changing amplitude and phase of a three-phase signal; generating a controllable amplitude controllable frequency three-phase signal, *αβ*-frame – *αβ* representation of a space phasor; realization of signal generators and signal conditioners in *αβ* frame; power in *αβ*-frame; control in *αβ*-frame; representation of systems in *αβ*-frame, *dq*-frame – *dq* representation of a space phasor; realization of signal generators and signal conditioners in *dq* frame; power in *dq*-frame; control in *dq*-frame; representation of systems in *dq*-frame, Averaged Model of a two-level VSC, Model of a two-level VSC in *αβ*-frame, Model of a two-level VSC in *dq*-frame *(Ref.1 – Chapters 4&5)*

Control of Grid-Imposed Frequency VSC in αβ-frame: Structure of grid-imposed frequency VSC System, Real/Reactive Power Control – Current-mode versus Voltage-mode control; Model of Real/Reactive Power Controller *αβ*-frame; Current-mode Control Real/Reactive Power in *αβ*-frame; Selection of DC Bus Voltage Level, Controlled DC Voltage Power Port – Model of Controlled DC Voltage Power Port in *αβ*-frame; DC Bus Voltage Control in *αβ*-frame. *(Ref.1 – Chapter 7)*

Control of Grid-Imposed Frequency VSC in dq-frame: Dynamic Model of Real/Reactive Power Controller *dq*-frame; PLL and Compensator for PLL; Current-mode Control Real/Reactive Power in *dq*-frame; Selection of DC Bus Voltage Level; AC Side equivalent circuit, Controlled DC Voltage Power Port – Model of Controlled DC Voltage Power Port in *dq*-frame; DC Bus Voltage Control in *dq*-frame. *(Ref.1 – Chapter 8)*

References:

1. Amirnaser Yazdani & Reza Iravani, *Voltage-Sourced Converters in Power Systems*, IEEE Press, John Wiley & Sons, 2010
2. Remus Teodorescu, Marco Liserre and Pedro Roderiguez Bin Wu, *High Power Converters and AC Drives*, IEEE Press, John Wiley & Sons, 2006
3. Remus Teodorescu, Marco Liserre and Pedro Rodriguez, *Grid Converters for Photovoltaic and Wind Power System'*, IEEE Press, John Wiley & Sons, 2011
4. Narain G. Hingorani and Laszlo Gyugyi, *Understanding FAC'*, IEEE Press, 2000.
5. Mohan, Ned, Tore M. Undeland, and William P. Robbins. *Power electronics: converters, applications, and design*. John wiley and sons, 2003.
6. Muhammad H. Rashid, *Power Electronics,* Third Edition, Pearson Education, 2004

EE6203E ADVANCED POWER SYSTEM OPERATION AND CONTROL

L	T	P	O	C
3	1	0	5	3

Pre-requisites: **NIL**

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyse the economic operation of Thermal and Hydro generating units
CO2: Apply conventional optimization techniques for evaluation of Unit Commitment problem
CO3: Evaluate Economic Load dispatch, Unit Commitment and Automatic Generation control problems
CO4: Determine the critical switching transient power systems
CO5: Examine travelling wave propagation on transmission lines

Unit commitment and economic dispatch
Economic operation - Load forecasting - Unit commitment – Economic dispatch problem of thermal units – Gradient method- Newton's method – Base point and participation factor method. Hydro-thermal co-ordination-Hydroelectric plant models – short term hydrothermal scheduling problem - gradient approach – Hydro units in series - pumped storage hydro plants-hydro - scheduling using Dynamic programming and linear programming – Real and Reactive Power Scheduling - Inter change evaluation and power pools-Economy interchange evaluation with unit commitments. Types of interchange. Energy banking-power pools.

Voltage and frequency control
Generation Control Loops. AVR Loop. Performance and Response. Automatic Generation Control of Single Area and Multi Area Systems. Static and Dynamic Response of AGC Loops – analysis using digital simulation - Economic Dispatch and AGC, AGC in a Deregulated Environment, Recent advances in AGC
MVAR control - Application of voltage regulator – synchronous condenser – transformer taps – static VAR compensators Ancillary Service Management – Frequency Control-Network Control-System Restart-Blackout -Restoration-Case Studies. Congestion Management-Indian Grid Code- Introduction to Power Systems Monitoring-SCADA-WAMS- Functions of Load Despatch Centre

Power system transients
Transients in electric power systems - Circuit closing transient – Recovery transient initiated by removal of short circuit – double frequency transient – Numerical techniques for transient Simulation - Damping of transients – Internal and external causes of over voltages-- Travelling waves in transmission lines – Circuits with distributed constants – Wave equations – Reflection and refraction of travelling waves – Travelling waves at different line terminations
Abnormal switching transients: Current chopping – Capacitance switching - Switching off of capacitor banks and reactor banks – Symmetrical components for solving three phase switching transients.

References:

1. Robert H. Miller, James H. Malinowski, *Power system operation*, Tata McGraw-Hill, 2009
2. Allen J. Wood, Bruce Wollenberg and Gerald B. Sheble, *Power Generation, Operation and Contro'*, 3rd Edition. John Wiley and Sons, 2013,
3. Abhijit Chakrabarti, Sunita Halder, *Power system Analysis-Operation & Control*, 3rd Edition, PHI, 2010.
4. T J Miller, 'Reactive Power Control in Electric Systems', Wiley, 1982.
5. Mini S. Thomas and John D. McDonald, *Power System SCADA and Smart Grids*, 1st Edition, CRC Press, 2015
6. Allan Greenwood, *Electrical Transients in Power System*, Wiley & Sons Inc. New York, 1991.
7. Philip C. Magnusson, Gerald C. Alexander, Vijai K Tripathi, Andreas Weisshaar, *Transmission lines and wave propagation*, CRC press, 2001.
8. Arieh L. Shenkman, *Transient analysis of Electric power circuits Handbook*, Springer, 2005.

EE6204E SIGNAL PROCESSING FOR POWER SYSTEMS

L	T	P	O	C
3	1	0	5	3

Pre-requisites: **NIL**

Total Lecture Sessions: 39

Course Outcomes:

CO1: Evaluate applications of Digital signal filtering techniques in power systems
CO2: Apply estimation techniques to evaluate power system parameters
CO3: Analyse different signal decomposition techniques
CO4: Evaluate the WAMS signal processing

Power Systems signals in terms of Smart Grid
Need for Signal Processing in Basics of power quality issues, Inrush Current in Power Transformers; Over-Excitation of Transformers; Transients in Instrument Transformers; Frequency Variation; Voltage Magnitude Variations; Voltage Frequency Variations, power system protection, Wide area dynamic analysis

Power Systems and signal processing
Stochastic gradient based algorithms – LMS algorithm, Normalized LMS algorithm, Gradient adaptive lattice algorithm. Mean-squared error behaviour, Convergence analysis, Prediction, filtering and smoothing, adaptive equalization, noise cancellation, blind deconvolution, adaptive IIR filters, RLS algorithms- GRLS, Gauss-Newton and RM. Basic Digital System, Parametric Notch FIR Filters; Sine and Cosine FIR Filters, Parametric Filters applications in smart grid,

Filters and Electrical Parameters Estimation
Forward and backward linear prediction, prediction error filters, AR lattice and ARMA Lattice – Ladder filters, Kalman filters, Wiener filter, Least Square methods for system modelling & Filter Design. Recursive least squares algorithms, Matrix inversion lemma, Spectrum estimation. Estimation of autocorrelation. Periodogram, Nonparametric and Parametric methods. Estimation Theory; Least-Squares Estimator; Frequency Estimation; Phasor Estimation; Phasor Estimation in Presence of DC Component; Spectrum Estimation; Windows; Frequency-Domain Windowing; Interpolation in Frequency Domain: Multitoned Signal.

Time-Frequency Signal Decomposition
Short-Time Fourier Transform; Sliding Window DFT; Filter Banks; Pattern Recognition, Feature Extraction on the Power Signal; Signal Detection for Electric Power Systems; Detection Theory.

Time-Frequency Signal Decomposition
Concepts of wavelet, s-transform, heartly s-transforms; Hillbert transform; Gabor transform and applications in power fluctuations: load fluctuations, wind farm power fluctuations and smart microgrid, Asset Management.

References

1. J.G.Proakis, M. Salehi, *Advanced Digital Signal Processing*, McGraw –Hill, 1992.
2. Paulo Fernando Ribeiro, Carlos Augusto Duque, Paulo Marcio da Silveira, Augusto Santiago Cerqueira, *Power Systems Signal Processing for Smart Grids*, John Wiley and Sons Ltd, 2014
3. Lizhe Tan Jean Jiang., *Digital Signal Processing Fundamentals and Applications [3rd Edition]*, Academic Press, 2018
4. Waldemar Rebizant, Janusz Szafran, Andrzej Wiszniewski, *Digital Signal Processing in Power System Protection and Control*, Springer-Verlag London Limited, 2011
5. CIGRE WG C4.07 (October, 2004) *Power quality indices and objectives.* Technical Report No 261. CIGRE/CIRED Working Group C4.07, Power Quality Indices and Objectives, CIGRE Technical Brochure TB 261, Paris.
6. Bollen, M.H.J. (2000) *Understanding Power Quality Problems: Voltage Sags and Interrruptions*, Wiley–IEEE Press.
7. Mitra, S.K, *Digital Signal Processing: A Computer Approac'*, McGraw–Hill Companies, Inc.2006.

8. IEC61869 1-9 (2007 to 2012) I*nstrument transformers: additional requirements. International Electrotechnical Commission*, Geneva, Switzerland.
9. Hamming, R. *Digital Filters*, Dover,1998.
10. Vaidyanathan, P.P, *Multirate Systems and Filter Banks*, Prentice Hall, Englewood Cliffs, New Jersey. 1993.
11. Sodney Burrus, C., Gopinath, R.A. and Guo, H. *Introduction to Wavelets and Wavelet Transforms: A Primer* , Prentice Hall, New Jersey. 1998
12. Bollen, M.H.J. and Gu, I.Y.H. *Signal Processing of Power Quality Disturbances*, IEEE Press and Wiley Interscience, NJ. 2006

EE6291E POWER SYSTEMS COMPUTATION LAB

Pre-requisites: **NIL**

L	T	P	O	C
0	0	2	1	1

Total Practical Sessions: 26

Course Outcomes:

CO1: Apply modern software tools for power system analysis
CO2: Develop software solutions for real life power system problems
CO3: Analyse the performance of different power converters
CO4: Prepare laboratory reports that clearly communicate experimental information in a logical and scientific manner.

List of Experiments

1. Formation of incidence matrices and bus admittance matrix of a power network. (MATLAB/PYTHON)
2. Power flow analysis of standard test systems using ETAP / Mi Power/ DigSilent power factory.
3. Short-circuit analysis of standard test systems using ETAP/ Mi Power/ DigSilent power factory.
4. Transient stability analysis of standard test systems using ETAP
5. ZBUS formation using building-up algorithm. (Using MATLAB/PYTHON)
6. Measurement of sequence reactance of 3-phase alternator and 3-phase transformer.
7. Travelling wave characteristics of transmission lines for different types of terminations using PSCAD.
8. Modeling and analysis of automatic load frequency control of multi-area power systems using MATLAB
9. Determination of synchronous machine reactance and time constant parameters.
10. Design and analysis of the following rectifier and inverter circuits
    a. Single- Phase and three-phase Inverters and rectifiers
    b. Phase Controlled Circuits
    c. Simulate FFT of three phase 6 pulse inverter using unipolar switching and bipolar switching.

Reference

1. Haadi A. Sadat, *Power System Analysis*, McGraw Hill Co. Ltd., India, 2000.
2. P. M. Anderson, A. A. Fouad, *Power system control and stability*, 2nd ed., John Wiley & Sons, 2008.
3. I.J. Nagarath, D.P. Kothari, *Power System Engineering*, Tata McGraw Hill Publishing Co. Ltd., NewDelhi, 1994.
4. Mariesa L. Crow, *Computational Methods for Electric Power Systems*, CRC Press, 2010.
5. Arthur R. Bergen, Vijay Vittal, *Power Systems Analysis*, Pearson Education, 2009.
6. P. Kundur, *Power System Stability and Control*, McGraw Hill Education Pvt Ltd, 2006.
7. K.R. Padiyar, *Power System Dynamics, Stability And Control*, Interline Publishing (P) Ltd.,Bangalore, 1999
8. M. A. Pai, Dheeman Chatterjee, *Computer Techniques in Power System Analysis*, McGraw Hill Education (India) Pvt Ltd., 2014. P
9. Ned Mohan, Power Electronics: Converters, Applications, and Design, John Wiley and Sons, 2006.
10. P.C. Sen, Power Electronics, Tata McGraw Hill, 2003.
11. G.K.Dubey et.al Thyristorised Power Controllers, Wiley Eastern Ltd., 2005.

EE6211E POWER SYSTEM STABILITY AND DYNAMICS

Pre-requisites: **NIL**

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: 39

Course Outcomes

CO1: Model and analyze dynamical systems to address various power system stability problems.

CO2: Execute digital simulation of large power system for small signal and transient stability analyses and develop stability enhancement methods.

CO3: Analyze the performance of single and multi-machine systems under transient, steady and dynamic conditions

CO4: Model and analyze voltage stability

Introduction to Power System Stability and Machine Modelling

Introduction to Power System Stability - Basic Concepts and definitions of Power System Stability - Classical Machine Model - Small-Disturbance Stability Analysis of SMIB system - Linearizing SMIB system swing equation - Equal area criterion - Critical Clearing Angle and Time - Disadvantages of Classical Model Representation of Synchronous Generators - Representation of Synchronous Machine Dynamics - Stator and rotor windings equations - Synchronous Reference Frame - Per Unit Representation - Sub-transient and transient reactance - Effect of Saturation on Synchronous Machine Modelling - Estimation of Synchronous Machine Parameters through Operational Impedance - Case studies and Digital Simulations

Small Signal Stability

Small signal angle instability (low frequency oscillations) - Power System Model for Low Frequency Oscillation Studies, damping and synchronizing torque analysis, Eigen value Analysis, Introduction to Non-linear stability Analysis. Improvement of System Damping with Supplementary Excitation Control, Standard models for PSS representation - sub-synchronous frequency oscillations - Sub Synchronous Resonance and Countermeasures, IEEE Benchmark models for SSR studies

Transient Stability

Transient Stability Problem, Modeling of Synchronous Machine, Loads, Network, Excitation Systems, Turbine and Governing Systems, Trapezoidal Rule of Numerical Integration Technique for Transient Stability Analysis, Simultaneous Implicit Approach for Transient Stability Analysis of Multi-machine Systems, Data for Transient Stability Studies, analysis using digital simulation - Transient Stability Enhancement Methods

Voltage Stability

Voltage Stability Problem. Real and Reactive Power Flow in Long Transmission Lines. Effect of ULTC and Load Characteristics on Voltage Stability. Voltage Stability Limit. Voltage Stability Assessment Using PV Curves. Modal analysis for voltage stability assessment. System Modelling-Static and Dynamic Analysis-Voltage Collapse Proximity Indices. Voltage Stability Improvement Methods.

References:

1. Vijay Vittal, James D. McCalley, Paul M. Anderson, A. A. Fouad, *Power System Control and Stability (IEEE Press Series on Power and Energy Systems),* 3rd Edition, Willey IEEE Press, 2019
2. Prabha S. Kundur, Om Malik, Power System Stability and Control, 2nd Edition, McGraw Hill 2022
3. K.R. Padiyar, *Power System Dynamics*, *Stability And Control*, Interline Publishing (P) Ltd., Bangalore, 1999
4. M A Pai, D P Sen Gupta, K R Padiyar, *Small Signal Analysis of Power Systems*, Narosa Series in Power and Energy Systems, 2004
5. C. Van Custem, T. Vournas, *Voltage Stability of Electric Power Systems*, Rlever Academic Press, 1998.
6. Yao-Nan-Yu, *Electric Power System Dynamics*, Academic Press, 1983
7. J. Arrilaga, C.P. Arnold, B.J. Harker, *Computer Modeling of Electrical Power Systems*, Wiley, New York, 1983.

EE6212E FACTS AND HVDC

Pre-requisites: **NIL**

Total Lecture Sessions: 39

L	T	P	O	C
3	1	0	5	3

Course Outcomes:
CO1: Identify the objectives of series and shunt compensation of power systems
CO2: Analyse the performance of Series, Shunt and combined FACTS controllers
CO3: Evaluate the performance of power systems with FACTS controllers
CO4: Analyse HVDC transmission with Current Source Converters and Voltage Source Converters
CO5: Synthesize controllers for LCC Based / Voltage Source Converters based HVDC Links

Introduction of FACTS Concepts & Controllers
FACTS Concepts: Transmission Interconnections, Flow of Power in an AC System, Limits the Loading Capability, Power Flow and Dynamic Stability Considerations of a Transmission Interconnection, Relative Importance of Controllable Parameters, Objectives of Shunt and Series compensation at transmission level in Power Systems
Basic FACTS Controllers: Basic of flexible alternating current transmission system (FACTS) controllers, shunt, series, combined and other controllers, HVDC or FACTS, Static VAr Compensator (SVC) using FC-TCR system and TSC-TCR system, Static Synchronous Compensator (STATCOM) and control, Thyristor Controlled Series Capacitor (TCSC) - Operation and Control, Static Synchronous Series Compensator (SSSC) and its control, Solid State Contactors (SSC) and TSSC.

Combined Compensators
Combined Compensators: Introduction, Circuit arrangement and operation of Unified power flow controller (UPFC) - Functions of Series and Shunt Converters in a UPFC - conventional power control capabilities - independent real and reactive power flow control, control structure, dynamic performance. Interline power flow controller (IPFC) basic operating principles, control structure, application considerations.

HVDC Transmission – LCC Based HVDC Links
Description of HVDC Transmission Systems – Types of DC Links – Monopolar Link – Bipolar Link – Homopolar Link – Ground return versus Metallic return – HVDC Transmission Link versus HVDC BTB (Back To Back) Link – Types of Converters: Line Commutated Converter – Description of various components in a LCC based HVDC Link –DC Cables and OH Lines – DC Breakers – Ground Electrodes for Monopolar operation.
Comparison of AC and DC Transmission – Limitations of AC System – Advantages of HVDC Transmission – Disadvantages of HVDC Transmission – Applications of HVDC Links and HVDC BTB Stations with examples of existing installations for various applications.
Line Commutated Converter(LCC) Based HVDC Links: Operation and quantitative relations for a 6-Pulse LCC in Rectifier and Inverter Mode with Mode1 Commutation overlap, Commutation Failure in Inversion mode, Reactive Power requirement of LCC-HVDC Links, Generation of Characteristic and Non-Characteristic Harmonics in the AC Side – Passive Filters for AC Side Filtering – Single tuned Filter, Double tuned filter, Damped filter – DC Side harmonics and filtering.
LCC-based HVDC Link Control: Steady-state equivalent circuits of a LCC HVDC Link – Steady-state relations for Rectifier mode and Inverter mode in terms of firing angle, firing advance angle and extinction angle – Current Margin Control principles – Link DC Voltage Control – Constant Extinction Angle Control – Power Reversal in the Link –

HVDC Transmission – VSC Based HVDC Links

VSC Based HVDC Links: Voltage Source Converters – Description of various VSC topologies used in practice - Description of various components in a VSC based HVDC Link – Advantages of VSC HVDC System – Disadvantages of VSC HVDC System – Comparison with LCC Based HVDC System.

Introduction to Modular Multilevel Converter Based VSC: Half-Bridge MMC Converter Operation – Capacitor Voltage Balancing Problem – Capacitor Voltage Balancing by Sequence Rotation – Capacitor Voltage Balancing by Min/Max Criterion – Nearest Level Modulation (NLM) for Sinusoidal Output in MMC – Techniques to implement NLM – Voltage Balancing by Capacitor Voltage Sorting.

Two-Level SPWM VSC HVDC Converter Control: Two-Level SPWM VSC Operation – Converter Control objectives: DC Side Voltage Control, DC Side Power Control, AC Side PCC Voltage Control, AC Side Reactive Power Control – Link Control in *dq* domain – Model of AC Side in *dq* domain – Model of DC Side in *dq* domain – Decoupling feedback in *dq* domain - Control block diagrams in *dq* domain for P_{dc} control, V_{dc} Control and PCC Voltage Control

Two-Level SPWM VSC HVDC Link Control: Control strategies for two-terminal VSC HVDC Links: Master-Slave Control Scheme – Voltage Margin Control Scheme – Handling of abnormal conditions in Voltage Margin Control – Voltage Margin Control Scheme using Dynamic Saturation Limits

References:

1. K R Padiyar, *FACTS Controllers in Power Transmission and Distribution*, New Age International Publishers, 2007.
2. X P Zhang, C Rehtanz, B Pal, *Flexible AC Transmission Systems- Modelling and Co*ntrol, Springer Verlag, Berlin, 2006.
3. N.G. Hingorani, L. Gyugyi, *Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems*, IEEE Press Book, Standard Publishers and Distributors, Delhi, 2001.
4. G T Heydt, *Power Quality*, McGraw-Hill Professional, 2007.
5. T J E Miller, *Static Reactive Power Compensation*, John Wiley and Sons, New York, 1982.
6. K.R. Padiyar, *HVDC Power Transmission System*, New Age Intl. Co, 2015
7. Dragan Jovcic, Khaled Ahmed, *High Voltage Direct Current Transmission: Converters, Systems and DC Grids*, Wiley Publishers, 2015
8. Jos Arrillaga, Yonghe H. Liu, Neville R. Watson, Nicholas J. Murray *Self-Commutating Converters for High Power Application*s, Wiley Publishers, 2009

EE6213E DIGITAL PROTECTION OF POWER SYSTEMS

Pre-requisites: **NIL**

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain various digital protective schemes for transmission lines and power apparatus.
CO2: Select and design instrument transformers for a specific protection scheme design.
CO3: Realise numerical relays in hardware platform.
CO4: Conduct testing and coordination of relays.

Art of relaying
Protective Relaying - Qualities of relaying - Definitions - Codes- Standards; Characteristic Functions; Classification – analog - digital- numerical; schemes and design-factors affecting performance –zones and degree of protection; faults-types and evaluation; Instrument transformers for protection.

Digital Relaying
Basic elements of digital protection –signal conditioning- conversion subsystems- relay units-sequence networks-fault sensing data processing units- FFT and Wavelet based algorithms: least square and differential equation based algorithms-travelling wave protection schemes; Relay Schematics and Analysis Over Current Relay-Instantaneous/Inverse Time – IDMT Characteristics; Directional Relays; Differential Relays- Restraining Characteristics; Distance Relays: Types Characteristics. Relay coordination- Relay setting calculations. Primary and backup protection, application and philosophy with applied relay engineering examples

Apparatus and System protection
Digital Protection of power system apparatus – protection of generators – Transformer protection – magnetizing inrush current – Application and connection of transformer differential relays – transformer over current protection. Bus bar protection - line protection - distance protection–long EHV line protection - Power line carrier protection Motors protection; Pilot wire and Carrier Current Schemes; Reactor protection – Protection of boosters - capacitors in an interconnected power system. System grounding –ground faults and protection; Load shedding and frequency relaying; Out of step relaying; Re-closing and synchronizing.

Advanced Protection Schemes
Integrated and multifunction protection schemes -SCADA based protection systems- Fault Tree Analysis; Testing of Relays- Field test procedures for protective relays. Adaptive relaying- AI & Fuzzy Based Protection, Intelligent Transmission Line Relaying Fault Detection

References:

1. A.G.Phadke, James S.Thorp, *'Computer Relaying for Power Systems'*, 2nd EJohn-Wiley and sons, 2009.
2. Waldemar Rebizant , Janusz Szafran, and Andrzej Wiszniewski. "*Digital Signal Processing in Power System Protection and Control"*, Springer Publication, 2011.
3. A.T.Johns and S.K.Salman*,'Digital Protection for Power Systems"* , IEEE Power Series, 1997
4. Stanley H. Horowitz, Arun G. Phadke, and Charles F. Henville. *'Power System Relaying'*, 5th Edition, John Wiley & Sons 2022
5. D N Vishwakarma, Badri Ram, and Soumya R Mohanty. '*Power System Protection and Switchgear'*, 3rd Edition. McGraw Hill, 2022
6. Latest IEEE Transactions papers on recent advancements in digital and adaptive relays
7. Latest Digital relay manuals of ABB, Siemens etc.

EE6214E POWER SYSTEM ECONOMICS AND DEREGULATION

Pre-requisite: **NIL**

Total Lecture Sessions: 39

L	T	P	O	C
3	1	0	5	3

Course Outcomes

CO1: Understand the principle and operation of deregulated power system.
CO2: Illustrate how electricity is priced in deregulated power markets.
CO3: Explain the working of various electricity markets around the world.
CO4: Understand the economics and business opportunities of utilities and end-consumers

Introduction to Deregulation
Why deregulate? – What to deregulate – Pricing power, energy, and capacity - Power supply and demand – Market structure and architecture – Spot market – Day ahead market – Real time market – Reserve market – Ancillary services - US and European market evolution - Reforms in Indian power sector

Energy and Derivative Markets
Concept of marginal cost - Market equilibrium – Market clearing price – Congestion pricing fundamentals – Locational marginal pricing – Operating reserve pricing – Value-of-lost-load pricing – Pricing losses on lines - Pricing losses at nodes **-** Derivative markets – Hedging risk – Contract for difference - Forwards - Futures – Options – Swaps

Power Generation Economics
Cost of Power Generation – Levelized Cost of Energy – Generation Planning – Investment Analysis– Time Value of Money – Net Present Value – Benefit/cost Ratio – Payback Period - Profit/investment Ratio – Business Economic Feasibility Study – Power Purchase Agreements

Distribution System and Microgrid Economics
Tariff and Energy Bills – Net Metering – Net Feed-in - Rooftop Solar PV Business models - Customer Savings Analysis – Grid Parity – Utility and DSO economics **-** Local energy markets – Virtual power plant and microgrids – Microgrid prosumer consortium – Role of DSO – Business models

References:

1. Daniel S. Kirschen, Goran Strbac, 'Fundamentals of Power System Economics, Wiley, 2018.
2. Darryl R. Biggar, Mohammad Reza Hesamzadeh, 'Economics of Electricity Markets', Wiley-IEEE press, 2014.
3. Mohammad Shahidehpour, Muwaffaq Alomoush, 'Restructured Electrical Power Systems: Operation: Trading, and Volatility', Marcel Dekker Inc., 2001.
4. Steven Stoft, 'Power System Economics: Designing Markets for Electricity', Wiley-IEEE Press, May 2002.
5. Anna Creti, Fulvio Fontini, 'Economics of Electricity', Cambridge University Press, May 2019.
6. Loi Lei Lai, 'Power System Restructuring and Deregulation', Wiley, 2001.
7. Jin Zhong, 'Power System Economic and Market Operations', CRC Press, 2018.
8. Kankar Bhattacharya, Math H. J. Bollen, Jaap E. Daalder, 'Operation of Restructured Power System', Springer, 2001.

EE6292E ADVANCED POWER SYSTEMS LAB

Pre-requisites: **NIL**

L	T	P	O	C
0	0	2	1	1

Total Practical Sessions: 26

Course Outcomes:
CO1: Apply modern software tools to assess the different state estimation techniques
CO2: Develop software solutions for the economic dispatch of various generation systems
CO3: Use dedicated software tools to analyse the power system under fault conditions
CO4: Use contingency analysis tools for power system security studies
CO5: Prepare laboratory reports that clearly communicate experimental information in a logical and scientific manner.

List of Experiments

1. Design and testing of PLL for Grid interconnection of renewable integrated systems
2. Performance analysis of a three-phase induction machine as an induction generator in the grid connected and self-excited modes
3. Performance analysis of a three-phase synchronous machine in the isolated and grid connected modes of operation.
4. Develop a program for WLS linear state estimation and Non –linear state estimation
5. Develop a program for DC load flow based WLS Sequential State Estimation.
6. Develop a program for Security constrained OPF using soft computing technique and simulate using application software.
7. Develop a programme to detect bad measurements
8. Write a program for security analysis using load flow & ranking of contingency.
9. Write a program for ranking of contingency using overload security analysis.
10. Implementation of algorithms based on undistorted sine wave approximation with 2-sample technique and 3-sample technique
11. Implementation of algorithms based on undistorted sine wave approximation with First and second derivative technique
12. Implementation of Sachdev's Least Square Error (LSQ) Algorithm.
13. Implementation of Fourier algorithms using DFT and Sliding DFT
14. Simulation of machine dynamics and analyse the effect of AVR, PSS models
15. Simulation of various faults in power system, Transient over voltages, travelling waves
16. Simulation of SSR
17. Stability studies – i) Large/small signal rotor angle stability ii) voltage instability.
18. Simulation of STATCOM & DSTATCOM, Active Power Filter, DVR, TCSC, UPQC

Note: Normally the practical classes are administered in two cycles of six experiments each. Depending on the availability of equipment and time, course coordinator may choose the experiments for each cycle.

Reference:

1. Haadi A. Sadat, *Power System Analysis*, McGraw Hill Co. Ltd., India, 2000.
2. P. M. Anderson, A. A. Fouad, *Power system control and stability*, 2nd ed., John Wiley & Sons, 2008.
3. I.J. Nagarath, D.P. Kothari, *Power System Engineering*, Tata McGraw Hill Publishing Co. Ltd., New Delhi, 1994.
4. Mariesa L. Crow, *Computational Methods for Electric Power Systems*, CRC Press, 2010.
5. Arthur R. Bergen, Vijay Vittal, *Power Systems Analysis*, Pearson Education, 2009.
6. P. Kundur, *Power System Stability and Control*, McGraw Hill Education Pvt Ltd, 2006.
7. K.R. Padiyar, *Power System Dynamics, Stability And Control*, Interline Publishing (P) Ltd., Bangalore, 1999
8. M. A. Pai, Dheeman Chatterjee, *Computer Techniques in Power System Analysis*, McGraw Hill Education (India) Pvt Ltd., 2014.

EE6293E PROJECT PHASE I

L	T	P	O	C
0	0	3	3	2

Pre-requisites: **NIL**

Course Outcomes:

CO1: Identify and review latest research papers for understanding emerging technologies in the field of power systems.
CO2: Identify a research problem in the areas of power systems and its feasible solutions by summarizing the reviewed papers.
CO3: Demonstrate the identified problem and its feasible solutions through basic simulations or experiments.
CO4: Document the identified problem and its feasible solutions through a detailed report and demonstrate through an oral presentation.

Each student has to choose a topic in the field of power systems, outside the M. Tech syllabus and identify latest relevant literature. Students have to identify a research problem in the field and study the feasible solutions available in the literature. Preliminary/basic experiments and/or simulations may be used for EE6193E PROJECT PHASE I. This project must be done by individual student under any faculty of the Electrical Engineering Department as the guide. Students have to submit a detailed report of the work and give an oral presentation before a panel of examiners.

EE7291E PROJECT PHASE II

Pre-requisites: **NIL**

L	T	P	O	C
0	0	6	3	3

Course Outcomes:

CO1: Review literature on any topic in the fields of power systems and formulate a research problem.
CO2: Apply relevant techniques and tools to arrive at feasible solutions for the problem formulated
CO3: Evaluate the solutions developed through simulations and/or experiments.
CO4: Document the problem formulation and its feasible solutions through a detailed report and demonstrate through an oral presentation.

Each student has to identify and formulate a research problem in the fields of power systems, develop solutions for it and validate the solutions through experiments and/or simulations. This project may/may not be a continuation of Project Phase I. This project can also be a preliminary work for the Project Phase III and IV. Faculty members propose projects /broad area of work and student will be asked to meet the faculty member who is offering the project of interest for guidance. This project must be done by individual student under any faculty member of the Electrical Engineering Department as the guide. Students can carry out their projects in R&D organizations/ industries which have facility in the proposed area with an officer from there as external guide and with internal guide from Department. This project is to be completed during the summer vacation period after the second semester. Students have to submit a detailed report of the work and give an oral presentation before a panel of examiners.

EE7292E PROJECT PHASE III

Pre-requisites: **NIL**

L	T	P	O	C
0	0	30	15	15

Course Outcomes:

CO1: Pursue their interest in power systems through design, research, theoretical and experimental approach

CO2: Identify a topic of interest and demonstrate the ability to carry out literature survey and select unresolved problems in the power systems domain of the selected project topic in

CO3: Gain the expertise to use new tools and techniques for development of cost-effective and environment friendly designs.

CO4: Effectively communicate by making an oral presentation of the progress of work before an evaluation committee, develop the ability to write good technical report and to publish the work in reputed conferences/journals.

Project Phase III - may or may not be the continuation of Project Phase I and/or Project Phase II in various topics in power systems. Faculty members propose projects /broad area of work and student will be asked to meet the faculty member who is offering the project of interest for guidance. Student can also select the topic for the interdisciplinary project too after discussions with guide. Students can carry out their projects in R&D organizations/ industries which have facility in the proposed area with an officer from there as external guide and with internal guide from Department. Students are required to undertake detailed technical work in the chosen area using one or more of the following: (i) Analytical models (ii) Computer simulations (iii) Hardware implementation. The assessment of the project will be done at the end of the semester by a committee. The students will present their project work before the committee. The complete project report is not expected at the end this semester. However, a 40–50 page typed concise report based on the work done will have to be submitted by the students to the assessing committee.

EE7293E PROJECT PHASE IV

Pre-requisites: **NIL**

L	T	P	O	C
0	0	30	15	15

Course Outcomes:

CO1: Develop comprehensive solution to issues identified in the project work and to meet the requirements as stated in project proposal.
CO2: Attain the results of the detailed analytical studies conducted, lay down validity and design criteria, for application to the power system problems.
CO3: Analyse the results critically, interpret the results and justify the achievement of the stated objectives.
CO4: Report the concept and detailed design solution and to effectively communicate the research contributions and publish in reputed journals/conference

EE7293E PROJECT PHASE IV may be a continuation of EE7292E PROJECT PHASE III in the third semester. Students should complete the work planned in the third semester, attaining all the objectives, and should prepare the project report of the complete work done in the two semesters. They are expected to communicate their research contributions in reputed conferences and/or journals.

EE6221E POWER QUALITY ISSUES AND REMEDIAL MEASURES

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture sessions: 39

Course Outcomes:

CO1: Explain various power quality issues, remedial measures and standards.

CO2: Develop models to analyse harmonics in networks and components

CO3: Design active power factor correction based on static VAR compensators and its control techniques

CO4: Analyze series and shunt active power filtering techniques for harmonic cancellation and isolation

CO5: Explain voltage quality improvement techniques and NEC grounding requirements and solutions to grounding and wiring problems

Power Quality Issues

Introduction-power quality-voltage quality-overview of power quality phenomena-classification of power quality issues-power quality measures and standards-THD-TIF-DIN-C-message weights-flicker factortransient phenomena-occurrence of power quality problems-power acceptability curves-IEEE guides,standards and recommended practices

Harmonic Analysis

Harmonics-individual and total harmonic distortion-RMS value of a harmonic waveform-triplex harmonics- important harmonic introducing devices-SMPS-Three phase power converters-arcing devices saturable devices-harmonic distortion of fluorescent lamps-effect of power system harmonics on power system equipments and loads. Modeling of networks and components under non-sinusoidal conditions transmission and distribution systems-shunt capacitors-transformers-electric machines-ground systems- loads that cause power quality problems-power quality problems created by drives and its impact on drives.

Power factor improvement

Power factor improvement- Passive Compensation- Passive Filtering- Harmonic Resonance- Impedance Scan Analysis- Active Power Factor Corrected Single Phase Front End Converters, Control Methods for Single Phase APFC- Three Phase APFC and Control Techniques- PFC Based on boost conversion technique and Bilateral Single Phase and Three Phase Converters. Static VAR compensators- SVC and STATCOM.

Active Harmonic Filtering Techniques

Active Harmonic Filtering-Shunt Injection Filter for single phase, three-phase three-wire and three-phase four-wire systems. d-q domain control of three phase shunt active filters- series active power filtering techniques for harmonic cancellation and isolation. Uninterruptible Power Supplies- Constant Voltage Transformers - Dynamic Voltage Restorers for sag, swell and flicker problems. Grounding and wiring - introduction - NEC grounding requirements-reasons for grounding-typical grounding and wiring problems-solutions to grounding and wiring problems.

References:

1. G.T. Heydt, *Electric power quality*, McGraw-Hill Professional, 2007.
2. Math H. Bollen, *Understanding Power Quality Problems*, IEEE Press, 2000.
3. J. Arrillaga, *Power System Quality Assessment*, John wiley, 2000.
4. E Fuchs, M.A.S. Masoum, *Power Quality in Power Systems and Electrical Machines*, Elsevier Inc.,2008.

A. Moreno, *Power Quality-Mitigation Technologies in a disturbed environment*, Springer, 2007.

5. W.E.Kazibwe, M.H.Sendaula, *Electric Power Quality Control Techniques*, Van Nostrand Reinhold,1993.
6. J. Arrillaga, B.C. Smith, N.R. Watson & A. R.Wood, *Power system Harmonic Analysis*, Wiley, 1997.
7. IEEE Transaction and IET Journal papers

EE6222E WIDE AREA MONITORING AND CONTROL OF POWER SYSTEMS

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Understand Synchrophasor Measurement Techniques
CO2: Implement and test wide area measurement systems
CO3: Realize optimal placement of PMU and state estimation using PMU dataCO4:
Monitor, analyse and control power system conditions in real time

Synchrophasors
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 MeasurementAlgorithms

Phasor Measurement Units and Phasor Data Concentrators
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 with PMU
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

WAMS applications
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.

References:

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*, Springer2008
3. Yong Li, Dechang Yang, Fang Liu, Yijia Cao, Christian Rehtanz, *Interconnected Power Systems:Wide-Area Dynamic Monitoring and Control Applications*, Springer, 2015
4. Ma J., Makarov Y., Dong Z, *Phasor Measurement Unit and its Applications on Modern Power Systems*, Springer, 2010
5. IEEE Power & Energy Society, *IEEE Standard for Synchrophasor Data Transfer for Power Systems*, IEEE New York, 2011
6. Xu B, Abur A, *Optimal Placement of Phasor Measurement units for State Estimation*, PSERC, FinalProject Report, 2005
7. P. M. Anderson, A. A. Fouad, *Power system control and stability*, 2nd ed., John Wiley & Sons, 2008
8. P. Kundur, *Power System Stability and Control*, McGraw Hill, New York, 1994.
9. Ali Abur, Antonio Gómez Expósito, *Power System State Estimation: Theory and Implementation*,CRC Press, 2004

EE6223E POWER SYSTEM RELIABILITY

Pre-requisite: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture sessions: 39

Course Outcomes

CO1: Model and assess reliability of systems undergoing stochastic events
CO2: Model variations in load demand and output of renewable energy sources
CO3: Apply probabilistic models to evaluation of power system reliability
CO4: Execute load flow algorithm with variable generation sources

Introduction to Probability and Statistics
Introduction to probability, probability density function, probability distribution function, Expectation, Variance, Covariance and Correlation and stochastic processes, Bernoulli Random Variable, Binomial Random Variable, Poisson Random Variable, Uniform Random Variable, Exponential Random Variable, Normal Random Variable, Weibull Random Variable

General reliability modeling and evaluation
System modeling for reliability; methods of reliability assessment: state space, cut-set and tie-set analysis, decomposition; Markov Approach

Reliability modeling and analysis of electric power systems
Modeling: generator modeling, transmission line modeling, load modeling; capacity outage table; probability and frequency distributions; unit addition algorithm; load modelling algorithm. Generation adequacy assessment using discrete convolution: discrete convolution of generation and load models; generation reserve model; determination of LOLP, LOLF, EUE; Distribution system reliability studies

Reliability of multi-node systems
Methods for multi-area and composite system analysis; contingency enumeration/ranking; equivalent assistance; stochastic/ probabilistic load flow; state space decomposition; Monte Carlo simulation, Analysis of risk in power systems; understanding of causes and remedial measures; Modelling of variable energy resources

References:

1. Chanan Singh, Panida Jirutitijaroen, Joydeep Mitra, Electric Power Grid Reliability Evaluation: Models and Method', 1st edition, Wiley-IEEE Press, 2018.
2. Marko Čepin, Assessment of Power System Reliability: methods and Applications', 1st edition, Springer, 2011.
3. G.F. Kovalev, L.M. Lebedeva, Reliability of Power Systems, 1st edition, Springer, 2019.
4. Wenyuan Li, Risk Assessment of Power Systems: Models, Methods, and Application', 2nd edition, Wiley-IEEE Press, 2014.
5. Roy Billington, Ronald N Allan, Reliability Evaluation of Power Systems, 2nd edition, Springer, 1996.

EE6224E PARALLEL AND DISTRIBUTED PROCESSING OF POWER SYSTEMS

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain functions of Distributed Energy Management Systems and Advantages of DistributedProcessing

CO2: Design of Parallel and Distributed processing algorithms for vertically Integrated Power Systems andRestructured Power Systems

CO3: Apply parallel and distributed processing algorithms for load Flow analysis, state estimation andsecurity assessment for power Systems

CO4: Design and implement distributed Control of Voltage and reactive Power and explain TransmissionCongestion Management

Distributed Energy Management Systems

Distributed Energy Management Systems: Functional Requirements of EMS - Complexity of Power Grid- Necessity for Distributed Processing - Vertically Integrated Power Systems-Central control center and Areacontrol center - SCADA - Distributed EMS- Restructured Power Systems- Advantages of Distributed Processing.

Parallel and Distributed systems

Parallel and Distributed Processing of Power systems: Parallel Systems- Distributed Systems- Comparison- Design of Parallel and Distributed algorithms- Distributed Processing of vertically Integrated Power Systems and Restructured Power Systems- Computer networks for Distributed Processing- Data Communication – Message Passing Interface

Parallel and distributed Load Flow

Parallel and distributed Load Flow: Mathematical Model- Parallel load flow Computation- Distributed load flow computation- System Partitioning and Algorithms- Parallel and distributed Load Flow for Distribution Systems-case studies and simulation results.

Parallel and distributed State Estimation: Components of State Estimation- Mathematical Model- Parallel State Estimation- Distributed State Estimation

Distributed Power System Security Analysis

Distributed Power System Security Analysis: Power System Security Analysis- - Distributed ContingencySelection, Distributed Static Security Analysis- Distributed Dynamic Security Analysis.

Distributed Control of Voltage and reactive Power- Decentralised closed loop primary control, distributedsecondary voltage/VAR control, Reactive Power Bidding, Centralized Tertiary voltage / VAR optimization. Transmission Congestion Management: Agent Based modeling – Multi Agent based Scheme forCongestion Management and Congestion mitigation.

References:

1. Mohammed Shahidehpour and Yauyu Wang, Communication and Control in Electric PowerSystems, John Wiley & Sons, 2005
2. Mariesa L. Crow, Computational Methods for Electric Power Systems, CRC Press, 2010.
3. J. Arrilaga, C.P. Arnold, B.J. Harker, Computer modelling of Electric Power Systems. Wiley, NewYork, 1983.
4. A.J. Wood, B.F. Wollenberg, Power Generation, Operation and Control, John Wiley & Sons, NewYork, 1984.
5. John J. Grainger and William D. Stevenson, Power System Analysis, Tata McGraw-Hill, 2003
6. Haadi A. Sadat, Power System Analysis, McGraw Hill Co. Ltd., India, 2000.
7. Mohammad Shahidehpour, M. Alomoush, Restructured Electrical Power Systems: Operation:Trading, and Volatility, CRC Press, 2001\

8. George L. Kusic, Computer Aided Power System Analysis, Prentice Hall of India (P) Ltd., NewDelhi, 1989.
9. Ali Abur, Antonio Gómez Expósito, Power System State Estimation: Theory and Implementation,CRC Press, 2004
10. Dimitri Bertsekas, John N. Tsitsiklis, Parallel and Distributed Computation: Numerical Methods,Prentice Hall Inc., 1989

EE6225E SMART GRID TECHNOLOGIES

Pre-requisites: **NIL**

Total Lecture sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Analyse the need and concept of Smart Grid

CO2: Assess the role of automation in Transmission and Distribution

CO3: Identify suitable communication networks for smart grid applications

CO4: Apply various distribution management function under autonomous operation

CO5: Differentiate different EMS and DMS functions

Introduction to Smart Grid

Introduction to Smart Grid: Introduction to Smart Grid - Working definitions of Smart Grid and Associated Concepts – Smart Grid Functions – Traditional Power Grid and Smart Grid – New Technologies for Smart Grid – Advantages – Indian Smart Grid – Key Challenges for Smart Grid.

Smart Grid Architecture

Smart Grid Architecture: Components and Architecture of Smart Grid Design – Review of the proposed architectures for Smart Grid. The fundamental components of Smart Grid designs – Transmission Automation – Distribution Automation

Energy Management System

Energy Management System (EMS) - Smart substations - Substation Automation - Feeder Automation, SCADA – Remote Terminal Unit – Intelligent Electronic Devices – Protocols, Phasor Measurement Unit – Wide area monitoring protection and control, Smart integration of energy resources – Renewable, intermittent power sources – Energy Storage.

Distribution Management System

Distribution Management System (DMS) – Volt / VAR control – Fault Detection, Isolation and Service Restoration, Network Reconfiguration, Outage management System, Customer Information System, Geographical Information System, Effect of Plug in Hybrid Electric Vehicles.

Advanced Metering infrastructure

Introduction to Smart Meters – Advanced Metering infrastructure (AMI), AMI protocols – Standards and initiatives, Demand side management and demand response programs, Demand pricing and Time of Use, Real Time Pricing, Peak Time Pricing.

Communication and networking

Elements of communication and networking – architectures, standards, PLC, Zigbee, GSM, BPL, Local Area Network (LAN) - House Area Network (HAN) - Wide Area Network (WAN) - Broadband over Power line (BPL) - IP based Protocols - Basics of Web Service and CLOUD Computing, Cyber Security for Smart Grid.

References:

1. Stuart Borlase *Smart Grid: Infrastructure, Technology and Solution'*, CRC Press 2012.
2. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama, *Smart Grid: Technology and Application*, Wiley, 2012.
3. Mini S. Thomas, John D McDonald, *Power System SCADA and Smart Grids,* CRC Press, 2015
4. Kenneth C.Budka, Jayant G. Deshpande, Marina Thottan, *Communication Networks for Smart Grids*, Springer, 2014.
5. Gil Masters, *Renewable and Efficient Electric Power System*, 2nd Edition Wiley–IEEE Press, 2013.

EE6226E DISTRIBUTED GENERATION AND MICROGRIDS

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Analyze the concept of distributed generation and technologies
CO2: Investigate the technical challenges of Distributed Generation technologies
CO3: Design the microgrid architectures and its control operation
CO4: Explore smartgrid technologies and infrastructure

Renewable Integration to Grid
Modern Power System: Generation - Transmission - Distribution - Loads - Introduction to Distributed Generation (DG) - Technologies of DG - IEEE 1547- Solar photovoltaic generation - wind energy - Wind power plants - Microturbines - Fuel Cell - Storage Systems - batteries, fly-wheels, ultracapacitors - unit sizing of DGs - Case studies

Distributed Energy Sources
Penetration of DGs Units in Power Systems - Integration of DGs Units in Distribution Network -Modern Power Electronics for DGs Applications – multiple and single input dc-dc converters - ac-dc and dc-ac converters - Technical restrictions - Protection of DGs - Economics of DGs –Pricing and Financing framework for DG units - Optimal placement of DGs - Case studies

Microgrid
Introduction to Microgrids - AC and DC microgrids - Operational Framework of Microgrids - anti-islanding schemes - Distribution Management System (DMS) - Microgrid System Central Controller (MGCC) - LocalControllers (LC) - Economic, environmental and operational benefits of Microgrids in a distribution network - Demand Response Management in Microgrids - Business Models and Pricing Mechanism in Microgrids -Interconnection of Microgrids

Smart Grid
Introduction to Smart Grids (SG) - Factors affecting the growth of SG - The global reality in the field of smartgrids and transition into future grids - Smart Agents - Electronics and communications infrastructure in SG
- ICT Technologies - smart meters - metering infrastructures - metering equipment - communication of metering equipment - communication protocols - Metering Data Management Systems (MDMS) - Application of SGs - Interconnections issues between SGs

References:

1. N. Hatziargyriou, *Microgrids: Architectures and Control*, Wiley-IEEE Press, 1st Edition, 2014
2. J. N. Twidell &A. D. Weir, *Renewable Energy Sources*, University press, Cambridge, 2001
3. James Larminie , Andrew Dicks , *Fuel Cell Systems*, John Weily & Sons Ltd, 2000
4. J. F. Manwell , J. G. McGowan, A. L. Rogers , *Wind Energy Explained*, John Weily & Sons Ltd2009
5. Loi Lei Lai, Tze Fun Chan, *Distributed Generation- Induction and Permanent Magnet Generators*,IEEE Press, John Wiley & Sons, Ltd., England. 2007.
6. Amirnaser Yezdani, and Reza Iravani, *Voltage Source Converters in Power Systems: Modeling,Control and Applications*, IEEE John Wiley Publications, 2009

EE6227E POWER SYSTEM AUTOMATION

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture sessions: 39

Course Outcomes:

CO1: Understand the concepts of power system automation.

CO2: Understand the components of SCADA systems.

CO3: Comprehend the RTU, IED and other components of automation systems

CO4: Understand the transfer of signals from the field to an operator control terminal.

CO5: Design an interoperable powers automation system

SCADA Systems

Evolution of Automation systems, History of Power system Automation, Supervisory Control And Data Acquisition (SCADA) Systems, Components of SCADA systems, SCADA Applications, SCADA in power systems, SCADA basic functions, SCADA application functions in Generation, Transmission and Distribution

Advantages of SCADA in Power Systems, The Power system 'Field' , Types of data & signals in the Power system, Flow of Data from the field to the SCADA Control center. Building blocks of SCADA systems, Classification of SCADA systems.

Remote Terminal Unit

Remote Terminal Unit (RTU), Evolution of RTUs, Components of RTU, Communication, Logic, Termination and Test/HMI Subsystems, Power supplies, Advanced RTU Functionalities.

Intelligent Electronic Devices

Intelligent Electronic Devices (IEDs), Evolution of IEDs , IED functional block diagram, The hardware and software architecture of IED, IED Communication subsystem, IED advanced functionalities, Typical IEDs, Data Concentrators and Merging Units, SCADA Communication Systems.

Distribution Management System

Master Station, Master station software and hardware configurations, Server systems in the master station, small, medium and large master station configurations, Global Positioning Systems, Master station performance, Human Machine Interface (HMI), HMI components, Software functionalities, Situational awareness, Case studies in SCADA.

References:

1. Mini S. Thomas, John D McDonald, *Power Systems SCADA and Smart Grid*, CRC Press, Taylor and Francis.
2. John D. Mc Donald, *Electric Power Substation Engineering* CRC Press, Taylor and Francis
3. James Northcote- Green, R Wilson, *Control and Automation of Electrical Power Distribution systems,* , CRC Press, Taylor and Francis.
4. James Momoh, *Electric Power Distribution, Automation, Protection and Control*, CRC press, Taylor and Francis.
5. Related Research papers.

EE6228E BIG DATA ANALYTICS IN POWER SYSTEMS

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand the concepts of data analytics in power systems.

CO2: Apply various machine learning and classifier algorithms to big data applications in power systems.

CO3: Analyse various techniques in data security in Smart Grid Communications

CO4: Apply various Optimization methods in data analytics

CO5: Apply the data analytics in power system operation, control and protection paradigms

Data in power systems

Introduction: Big Data-Future Power Systems-Big Data Application and Analytics in a Large-Scale Power System-Role of Big Data Analytics in Smart Grid Communications-Big Data Optimization in Electric Power Systems: A Review - Security Methods for Critical Infrastructure Communications- Data Mining Methods for Electricity Theft Detection - Unit Commitment Control of Smart Grids - Data-Based Transformer Differential Protection

Big data application in large-scale power system

Big Data Application and Analytics in a Large-Scale Power System: General Applications of Big Data-Health Care-Social Networking-Handling Big Data. Algorithms for Processing Big Data-Machine Learning and Deep Learning Generalities. Machine Learning- Artificial Neural Network (ANN) Model-Support Vector Machine (SVM)- Decision-Tree Classifier. Deep Learning-Deep Learning Models-Challenges and Suggested Solutions for Using Deep Learning in Big Data Analytics. Application of Big Data in Power Systems-Big Data in Smart Grid Networks-Phasor Measurement Units (PMU)- Renewable Energy-CIM as Information Standard for Big Data Analytics-Big Data Problem in Power System Modeling-Security-Constrained Unit Commitment (SCUC)- Decomposition Methods to Handle Big Data-Firm Transmission Right (FTR) Problems-Time-Constrained Economic Dispatch

Big Data security in Smart Grid Communications

Role of Big Data in Smart Grid Communications: Grid Modernization-Grid Interconnection with the Internet of Things-Data Traffic Pattern in a Smart Grid Environment-Phasor Measurement Unites Applied to Distribution Systems-Advanced Metering Infrastructure (AMI)- Massive Flow of Information in a Smart Scenario-Volume of Generated Data in a Smart Distribution System: Case Studies-Generated Data by PMUs-Generated Data by Metering Infrastructure - Data Mining Methods for Electricity Theft Detection: Introduction-Transmission and Distribution System Losses-Electricity Theft Methods-Fraud-Bypassing Existing Meetings-Meter Tampering-Billing Issues-Outright Theft-Electricity Theft and Data Collection-Data Mining and Electricity Theft-Prediction-Classification and Clustering-Issues and Directions in Electricity Theft-Related Data-Mining Research

Big Data Optimization in Electric Power Systems

Big Data Optimization in Electric Power Systems: Background-Scientometric Analysis of Big Data-Big Data and Power Systems-Big Data Optimization-Application of Big Data in Power System Studies. Optimization Techniques Used in the Big Data Analysis-Computational Method for Large-scale Unconstrained Optimization - Numerical Approach for Non-smooth Large-scale Optimization-Big Data in Logistics Optimization-Big Data Analytics Based on Convex and Nonconvex Optimization-Metaheuristic Algorithms for Big Data Optimization

Data in control and protection

Multi-agent Architecture-Smart Grid Using Multi-Agent Model-Agent's Profle-Decision-Making Method-Storing and Selling Extra Power Procedure-Examples

Protection Algorithm Based on Data Pattern Recognition: Big Data and Power System Protection-Methods for Differential Protection Blocking - Harmonic Restraint and Harmonic Blocking-Methods Based on Waveform Recognition - Principal Component Analysis-Curvilinear Component Analysis (CCA)- PCA Applied to Discriminate Between Inrush and Fault Currents in Transformers- Application of the CCA as a Base for a Differential Protection

References

1. Ahmed F. Zobaa and Trevor J. Bihl [Edited], *Big Data Analytics in Future Power Systems*, CRC Press,Taylor & Francis Group, 2019
2. Reza Arghandeh and Yuxun Zhou [Edited]., *Big Data Application in Power Systems*, Elsevier, 2018
3. Robert C. Qiu and Paul Antonik, *Smart Grid using Big Data Analytics: A Random Matrix Theory Approach*, John Wiley & Sons Ltd, 2017
4. Patrick C. K. Hung [Edited],*Big Data Applications and Use Cases,* Springer International Publishing Switzerland 2016

EE6229E POWER DISTRIBUTION SYSTEMS

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes

CO1: Describe and apply general concepts of distribution system, load and energy forecasting
CO2: Analyze distribution system and carry out network cost modelling
CO3: Analyze distribution system reliability and assess power quality
CO4: Describe consumer tariffs, costing and pricing
CO5: Describe and apply the knowledge of Power capacitors in HT and LT installation
CO6: Study the aspects of distribution system design and automation

Distribution System Parameters, Architecture, and Design

Distribution system - General concepts and architectures - Load and energy forecasting - Factors in power system loading - Optimization of distribution system network cost modeling - Economic loading of distribution transformers Consumer services - consumer load control for power shortages - Tariffs-costing, pricing and metering – Overhead and underground lines - Optimum design considerations - Sizing of capacitors – Voltage design calculations

Distribution System Automation and communication

Distribution Automation System: Necessity, System Control Hierarchy - Basic Architecture and implementation Strategies for SCADA and DAC systems - Basic Distribution Management System Functions. Communication Systems for Control and Automation - Wireless and wired Communications - SCADA and DAC communication Protocols, Architectures and user interface

Distribution System Reliability and Power Quality

Electric power quality: Basic definitions – Power quality problems – Voltage variations and quality measures – Harmonics and mitigation

System reliability: Basic definitions and mathematics – Series systems, parallel systems and their combinations – Markov process – Development of state transition models – Interruption indices -

Distribution System Analysis

Load flow analysis of balanced and unbalanced radial distribution system – Load flow analysis of weakly meshed system - Short circuit analysis of balanced and unbalanced radial distribution system - Short circuit analysis of weakly meshed system – Types of faults

References

1. Turan Gonen, Electric Power Distribution Engineering, 3rd edition, CRC Press, 2015
2. Sallam A. A, & Malik O. P, Electric Distribution Systems, 2nd edition, Wiley-IEEE Press, 2018
3. B. Das, Power Distribution Automation, IET Power and Energy Series, 2016
4. J. J. Burke, Power Distribution Engineering: Fundamentals and Applications, CRC Press, 1994
5. J. A. Momoh, Electric Power Distribution, Automation, Protection, and Control, CRC Press, 2007
6. T. A Short, Electric Power Distribution Handbook, CRC Press, 2018

EE6230E DEVELOPMENT AND EVALUATION OF POWER PROJECTS

Pre-requisite: **NIL**

Total lecture sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes

CO1: Do a basic cost-benefit analysis of power projects in generation, transmission, and distribution
CO2: Study the different business models in power systems
CO3: Study the different metering techniques
CO4: Analyze and evaluate the economics of power projects through case studies

Considerations in Project Development and Evaluation
Value of Electricity – Integrated Resource Planning – Environmental Concerns and Efficiency – Energy Return on Energy Invested – Capacity Factor – Rehabilitating, Retrofitting and Repowering of Existing Power Facilities - Global Electrical Power Scene - Project Selection and Evaluation – Project Development – Pre-investment stage – Investment Stage – Operational Stage – Post Operational Phase

Evaluation of Power Generation Projects
Cost of Power Generation – Levelized Cost of Energy – Generation Planning – Investment Analysis– Time Value of Money – Net Present Value – Benefit/cost Ratio – Payback Period - Profit/investment Ratio – Business Economic Feasibility Study – Power Purchase Agreements – Case studies on development and evaluation of renewable and non-renewable energy projects

Investing in Transmission
The Nature of the Transmission Business – Barriers to transmission development – Macrogrid proposals - Cost-Based Transmission Expansion – Value-Based Transmission Expansion – TSO economics – Interregional coordination – Cost-Benefit Analysis

Distribution System Finance
Tariff and Energy Bills – Financing Distributed Generation Projects – Net Metering – Net Feed-in - Rooftop Solar PV Business models – Grid-Connected and Stand-alone PV systems - Customer Savings Analysis – Grid Parity – Utility and DSO economics

References:

1. Hisham Khatib, Economic Evaluation of Projects in the Electricity Supply Industry, 3rd edition, IET, 2014.
2. Marcelino Madrigal and Steven Stoft, Transmission Expansion for Renewable Energy Scale-Up, 2012, Washington DC, World Bank.
3. Santosh Raikar, Seabron Adamson, Renewable Energy Finance: Theory and Practice, Elsevier, 2019.
4. Daniel S. Kirschen, Goran Strbac, Fundamentals of Power System Economics, Wiley, 2018.
5. Steven Stoft, Power System Economics: Designing Markets for Electricity, Wiley-IEEE Press, 2002.

ZZ6001E RESEARCH METHODOLOGY

Pre-requisites: **NIL**

L	T	P	O	C
2	0	0	4	2

Total Lecture sessions: 26

Course Outcomes

CO1: Explain the basic concepts and types of research

CO2: Develop research design and techniques of data analysis

CO3: Develop critical thinking skills and enhanced writing skills

CO4: Apply qualitative and quantitative methods for data analysis and presentation

CO5: Implement healthy research practice, research ethics, and responsible scientific conduct

Exploring Research Inquisitiveness

Philosophy of Scientific Research, Role of Research Guide, Planning the Research Project, Research Process, Research Problem Identification and Formulation, Variables, Framework development, Research Design, Types of Research, Sampling, Measurement, Validity and Reliability, Survey, Designing Experiments, Research Proposal, Research Communication, Research Publication, Structuring a research paper, structuring thesis/ dissertation,

Research Plan and Path

Developing a Research Plan: Reviewing the literature- Referencing – Information sources – Information retrieval – Role of libraries in information retrieval – Tools for identifying literatures – Reading and understanding a research article – Critical thinking and logical reasoning; Framing the research hypotheses, Converting research Question into a Model; Data collection- Types of data-Dataset creation- Primary and Secondary data- Scales of measurement- Sources and collection of data- Processing and analysis of data-Understanding Data-statistical analysis, displaying of data-Data visualization-Data interpretation; Research design- Qualitative and Quantitative Research- Designing of experiments- Validation of experiments- Inferential statistics and result interpretation

Scientific Conduct and Ethical Practice

Plagiarism– Ethics of Research- Scientific Misconduct- Forms of Scientific Misconduct. Plagiarism, Unscientific practices in thesis work-Conduct in the workplace and interaction with peers – Intellectual property: IPR and patent registration, copyrights; Current trends – Usage and ethics of AI tools in scientific research.

References:

1. Leedy, P D, *Practical Research: Planning and Design*, USA: Pearson, Twelfth ed., 2018.
2. Krishnaswamy, K. N., Sivakumar, A. I., and Mathirajan, M., *Management Research Methodology*, Pearson Education, 2006.
3. Tony Greenfield and Sue Greener., *Research Methods for Postgraduates*, USA: John Wiley & Sons Ltd., Third ed., 2016.
4. John W. Creswell and J. David Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, USA: Sage Publications, Sixth ed., 2022.

MS6174E TECHNICAL COMMUNICATION AND WRITING

Pre-requisites: **NIL**

L	T	P	O	C
2	1	0	3	2

Total Lecture Sessions: 26

Course Outcomes:

CO1: Apply effective communication strategies for different professional and industry needs.
CO2: Collaborate on various writing projects for academic and technical purposes.
CO3: Combine attributes of critical thinking for improving technical documentation.
CO4: Adapt technical writing styles to different platforms.

Technical Communication
Process(es) and Types of Speaking and Writing for Professional Purposes - Technical Writing: Introduction, Definition, Scope and Characteristics - Audience Analysis - Conciseness and Coherences - Critical Thinking - Accuracy and Reliability - Ethical Consideration in Writing - Presentation Skills - Professional Grooming - Poster Presentations

Grammar, Punctuation and Stylistics
Constituent Structure of Sentences - Functional Roles of Elements in a Sentence - Thematic Structures and Interpretations - Clarity - Verb Tense and Mood - Active and Passive Structures - Reporting Verbs and Reported Tense - Formatting of Technical Documents - Incorporating Visuals Elements - Proofreading

Technical Documentation
Types of Technical Documents: Reports, Proposals, Cover Letters - Manuals and Instructions - Online Documentation - Product Documentation - Collaborative Writing: Tools and Software - Version Control Document Management - Self Editing, Peer Review and Feedback Processes

References:

1. Foley, M., & Hall, D., Longman advanced learner's grammar, a self-study reference & practice book with answers. Pearson Education Limited, 2018.
2. Gerson, S. J., & Gerson, S. M., Technical writing: Process and product, Pearson, 2009.
3. Kirkwood, H. M. A., & M., M. C. M. I., Hallidays introduction to functional grammar (4th ed.), Hodder Education, 2013.
4. Markel, M., Technical Communication (10th ed.). Palgrave Macmillan, 2012.
5. Tuhovsky, I., Communication skills training: A practical guide to improving your social intelligence, presentation, Persuasion and public speaking skills, Rupa Publications India, 2019.
6. Williams, R., The Non-designer's Design Book. Peachpit Press, 2014.

IE6001E ENTREPRENEURSHIP DEVELOPMENT

Pre-requisites: **NIL**

Total Lecture Sessions: 26

L	T	P	O	C
2	0	0	4	2

Course Outcomes:

CO1: Describe the various strategies and techniques used in business planning and scaling ventures.
CO2: Apply critical thinking and analytical skills to assess the feasibility and viability of business ideas.
CO3: Evaluate and select appropriate business models, financial strategies, marketing approaches, and operational plans for startup ventures.
CO4: Assess the performance and effectiveness of entrepreneurial strategies and actions through the use of relevant metrics and indicators.

Entrepreneurial Mindset and Opportunity Identification
Introduction to Entrepreneurship Development - Evolution of entrepreneurship, Entrepreneurial mindset, Economic development, Opportunity Recognition and Evaluation - Market gaps - Market potential, Feasibility analysis - Innovation and Creativity in Entrepreneurship - Innovation and entrepreneurship, Creativity techniques, Intellectual property management.

Business Planning and Execution
Business Model Development and Validation - Effective business models, Value proposition testing, Lean startup methodologies - Financial Management and Funding Strategies - Marketing and Sales Strategies - Market analysis, Marketing strategies, Sales techniques - Operations and Resource Management - Operational planning and management, Supply chain and logistics, Stream wise Case studies.

Growth and Scaling Strategies
Growth Strategies and Expansion - Sustainable growth strategies, Market expansion, Franchising and partnerships - Managing Entrepreneurial Risks and Challenges - Risk identification and mitigation, Crisis management, Ethical considerations - Leadership and Team Development - Stream wise Case studies.

References:

1. Kaplan, J. M., Warren, A. C., & Murthy V., Patterns of entrepreneurship management. John Wiley & Sons, 2022.
2. Kuratko, D. F., Entrepreneurship: Theory, Process, and Practice. Cengage learning.
3. Barringer, B. R., Entrepreneurship: Successfully launching new ventures, Pearson Education India, 2015.
4. Rajiv Shah, Zhijie Gao, Harini Mittal, Innovation, Entrepreneurship, and the Economy in the US, China, and India, Academic Press, 2014.
5. Sundar,K., Entrepreneurship Development, 2nd Ed., Vijaya Nichkol Imprints, Chennai, 2022.
6. E. Gordon,Dr. K. Natarajan., Entrepreneurship Development, 6th Ed, Himalya Publishers, Delhi, 2017.
7. Debasish Biswas, Chanchal Dey, Entrepreneurship Development in India, Taylor & Francis, 2021.