Course Structure & Curriculum

For

M. Tech. Programme

In

Electrical Engineering

With Specialization in

Power System

(Effective from Session 2017-18)

Department of Electrical Engineering
Motilal Nehru National Institute of Technology Allahabad

Teliarganj, Allahabad-211004, Uttar Pradesh

MOTILAL NEHRU NATIONAL INSTITUTE OF TECHNOLOGY ALLAHABAD

VISION

To establish a unique identity for the institute amongst national and international academic and research organizations through knowledge creation, acquisition and dissemination for the benefit of society and humanity.

MISSION

- To generate high quality human and knowledge resources in our core areas of competence and emerging areas to make valuable contribution in technology for social and economic development of the nation. Focused efforts to be undertaken for identification, monitoring and control of objective attributes of quality and for continuous enhancement of academic processes, infrastructure and ambience.
- To efficaciously enhance and expand, even beyond national boundaries, its contribution to the betterment of technical education and offer international programmes of teaching, consultancy and research.

DEPARTMENT OF ELECTRICAL ENGINEERING

VISION

To produce globally competitive technical manpower with sound knowledge of theory and practice, with a commitment to serve the society and to foster cutting edge research in Electrical Engineering pertaining to the problems currently faced by the country and the world.

MISSION

1. Develop state of art lab facilities for research and consultancy
2. Develop infrastructure and procure-cutting edge tools/equipment
3. Develop relevant content and capability for quality teaching
4. Improve symbiotic relationship with Industry for collaborative research and resource generation.

M.Tech. (Electrical Engineering) with specialization in Power Systems

Course Structure & Scheme of Evaluation (Effective from Session 2017-18)

I Semester

Subject Code	Subject Name	L	T	P	Credits				Total Marks
						TA	MSE	ESE	
EE 21105	Advanced Power System Operation & Control	3	1	0	4	20	20	60	**100**
EE 21106	Advanced Power System Protection	3	1	0	4	20	20	60	**100**
EE 213xx	Elective I	3	1	0	4	20	20	60	**100**
EE 213xx	Elective II	3	1	0	4	20	20	60	**100**
EE 213xx	Elective III	0	0	6	4	50	0	50	**100**

Total Credits = 20

II Semester

Subject Code	Subject Name	L	T	P	Credits				Total Marks
						TA	MSE	ESE	
EE 22125	Economic Operation of Power System	3	1	0	4	20	20	60	**100**
EE 22126	Distributed Generation Systems	3	1	0	4	20	20	60	**100**
EE 223xx	Elective IV	3	1	0	4	20	20	60	**100**
EE 223xx	Elective V	3	1	0	4	20	20	60	**100**
EE 223xx	Elective VI	0	0	6	4	50	0	50	**100**

Total Credits = 20

III Semester

Subject Code	Subject Name	Credits	Eval (100)
EE 23653	State of Art Seminar	4	Marks
EE 23603	Thesis	16	Marks

IV Semester

Subject Code	Subject Name	Credits	Eval (100)
EE 24613	Thesis	20	Marks

Note-1: The distribution of thesis evaluation marks will be as follows:

1. Supervisor(s) evaluation component 60%
2. Oral Board evaluation component 40%

EE 21105 Advanced Power System Operation & Control FIRST SEMESTER

Modeling of power system components: Synchronous machine; current & flux linkage modelsusing Park's transformation, inductance matrices, voltage equations, time constants, Simplified models; third-order, fourth-order, fifth-order, sixth-order models, Excitation systems and Prime mover, steam and hydro turbine control.

Power system stability: Definition, types and classification of stability in power system, Small signal stability, Mid-term and long term stability, Analysis of stability in simple system, Heffron-Phillips model.

Oscillations in Power System: Swing equation in single machine infinite bus system, multi-machine system, Type of oscillations, inter-area oscillations, local mode oscillations, analytical tools to detect these oscillations, controls for the local mode oscillations and global control for handling inter-area oscillations, damping controllers (PSS, DVR), PSS structure, PMUs, Wide area monitoring system, Real time monitoring of stability (oscillation frequency and damping factor), Global controllers for inter-area oscillation damping (FACTS controller applications).Examples of major black-outs world-wide and in India, Sequences of their occurrences.

Control of power system: Control of active and reactive power, control structure for frequency control; primary and secondary loop, static and dynamic characteristic of primary control in islanded and 2-generator system, role of speed droop, load frequency control; automatic generation control. Voltage control mechanisms; use of machine excitation system and AVR, Reactive power compensation devices, different FACTS devices and their characteristics.

Power flow solution in a large standard bus network.

References:

1. Prabha Kundur, *Power system stability and control*, Tata McGraw Hill Edition,1994.
2. K R Padiyar, *Power System Dynamics stability and control*, 2002.
3. Stagg and El-Abiad, *Computer Methods in Power System Analysis,* McGraw Hill Publications,1968.
4. P.S.R. Murthy, *Power System Operation &Control*, Tata McGraw Hill Edition,1984.
5. R.N Dhar, *Computer Aided Power System Operation and Analysis*, McGraw Hill Publications,1983.
6. George L. Kusic, *Computer Aided Power System Analysis* - Prentice Hall Publication, 1986.

EE-21106 Advanced Power System Protection **FIRST SEMESTER**

Evolution of relays from electromechanical relays. Comparators and Level Detectors: Static Relay Functional circuits, Amplitude and Phase comparators, level detectors. Performance and operational characteristics of digital protection. Digital Relays, Microprocessor based protective relays. Mathematical background to protection algorithms:

Finite difference techniques, Interpolation formulas: forward, backward and central difference interpolation. Numerical differentiation, Curve fitting and smoothing, Least squares method, Fourier analysis, Fourier series and Fourier transform, Walsh function analysis.

Digital signal processing –digital filtering in protection relays- numeric protection –testing Digital filtering in protection relays – digital data transmission– relay hardware – relay algorithms. Concepts of modern coordinated control system.

Protection algorithms: Sinusoidal wave based algorithms: Sample and first derivative (Mann and Morrison algorithm) Fourier and Walsh based algorithms: Fourier algorithm: Full cycle window algorithm, fractional cycle window algorithm. Walsh function based algorithm.

Other algorithms: Least squares based algorithms. Differential equation based algorithms. Travelling wave based techniques.

Digital differential protection of Electrical Power system: Digital transformer protection. Digital line differential and distance protection. Digital protection of motors

Recent advances in digital protection of power systems. New technology inmicro-grids.Communication protocols applied in the protection.

References:

1. A.T. Johns and S.K. Salman,Digital Protection for Power Systems, Peter Peregrinus Ltd. on behalf of the IEE London U.K.,1995
2. Arun G. Phadke and J.S. Thorp, Computer Relaying for Power Systems, John Wiley and Sons Ltd. England and Research Studies Press Ltd,2009
3. Badri Ram and D.N. Vishvakarma, Power System Protection and Switchgear, TMH, New Delhi,2001
4. Areva, Network Protection Application Guide,1966

EE 22125 Economic Operation of Power System SECOND SEMESTER

Economic Load Dispatch Problem: Characteristics of steam and hydro electric generation units, classical methods for economic operation, formulation of optimization problem, Economic Dispatch Problem neglecting Transmission Losses, optimal generation scheduling problem considering Transmission Losses, transmission loss expression, Incremental Transmission Loss, Solution of optimization problem.

Optimal Unit Commitment: Economic dispatch versus Unit Commitment, Need for Unit Commitment, Constraints in Thermal and Hydro Units, Cost function formulation, Unit Commitment solution Methods.

Optimal Unit Commitment Methods: Priority List Schemes, Dynamic Programming method, Lagrange Relaxation method, Reliability considerations in Optimal Unit Commitment, Security constraint, Startup considerations.

Optimal power flow without/ with inequality constraints, penalty function method; Importance of Hydro-Thermal Coordination, Mathematical modeling of long-term Hydro-Thermal Coordination, Kirchmayer's method for short-term Hydro-Thermal Coordination, Advantages of Hydro-Thermal Plant Coordination, Application of evolutionary algorithms in optimal power flow.

References:

1. Modern Power System Analysis, D. P. Kothari, and I. J. Nagrath, Tata McGraw-Hill Education, 2003.
2. Power System Operation and Control, S. Sivanagaraju and G. Sreenivasan, Pearson Education India, 2009.
3. Power System Optimization, D.P.Kothari, and J. S. Dhillon, PHI Learning Pvt. Ltd., 2010.
4. Economic Control of Interconnected Systems, L. K. Kirchmayer, Wiley, 1959.

EE 22126 Distributed Generation Systems — SECOND SEMESTER

Introduction: Overview of power, DG definition, Distributed generation advantages and needs, Basic models of DG systems, Integration in power systems.

Generation resources: Photovoltaic, Solar-thermal power generation, Wind power generation, Other renewables like geothermal, tidal, wave, etc.

Effects of renewable energy into the grid; Stability, Supply guarantee and power quality, Issues related to bidirectional power flow on network; voltage control, system protection.

Energy storage: Battery, Ultra capacitors, Flywheel, Compressed air, etc.

Electric Vehicles: EV interests, Random generation forecast corrections, **-** EV needs according to users and grid exigencies, Dimension and security according to EV needs, **-** Batteries and chargers, Standard UNE 61851. EV conductive system

Micro-Grid: Resources evaluation and needs, Dimensioning integration systems, Optimizing integration systems, integration systems control, Case study: multi-generation buildings.

Distributed Generation Protection: Islanding- Definition, detection approach, Protection approach.

Economic and financial: Aspects of distributed generation, the regulatory environment and standards.

Smart grid: Concepts, Application of ICT in smart grid.

References:

1. A.J. Pansini, *Guide to Electrical Power Distribution Systems*, 2005, The Fairmont Press Inc.
2. Ann-Marie Borbely, Jan F. Kreider, *Distributed Generation*, 2001, CRC Press.
3. Felix A. Farret and M. Godoy Simoes, *Integration of Alternative Sources of Energy,* John Wiley and Sons, 2006.
4. Bollen, Hassan, Integration of Distributed Generation in the Power System, Wiley- IEEE Press, 2011.
5. H. Lee Willis, Walter G. Scott, *Distributed Power Generation, Planning & Evaluation*, CRC Press Taylor & Francis Group, 2000.

List of Electives for Power System

List of Subjects in Elective I

1. EE 21321 Flexible AC Transmission Systems
2. EE 21322 Advanced Energy Management System
3. EE 21323 EHV Transmission Technologies
4. EE 21301 Optimization Techniques

List of Subjects in Elective II

1. EE 21324 Power Quality and Mitigation
2. EE 21325 Renewable Energy & Grid Integration
3. EE 21326 Computer Aided Power System Analysis
4. EE 21308 Virtual Instrumentation

List of Subjects in Electives III

1. EE 21333 Advanced Power System and Protection Lab.
2. EE 21339 Mini Project

List of Subjects in Elective IV

1. EE 22361 Distribution Automation
2. EE 22362 Reliability Engineering
3. EE 22363 HVDC Transmission
4. EE 22351 Electric Traction and Vehicles

List of Subjects in Elective V

1. EE 22364 Power System Planning
2. EE 22365 Power System Communication
3. EE 22366 Power System Dynamics
4. EE 22356 Active Power Conditioning

List of Subjects in Electives VI

1. EE 22363 Modelling and Simulation of Power Network Lab.
2. EE 22369 Mini Project

EE 21321 Flexible AC Transmission Systems **FIRST SEMESTER (E-I)**

Introduction to FACTS, challenges and needs, Power Flow in AC transmission line, Power flow control, Description and definition of FACTS controllers, Static power converter structures, Voltage-sourced and current-sourced converters, Converter output and harmonic control, power converter control issues, Shunt Compensation: SVC, STATCOM, Operation and control, Configurations and applications, Series Compensation: TCSC, mitigation of sub-synchronous resonance, SSSC, Combination of shunt-series compensation: UPFC, Power flow studies with FACTS controllers, operational constraints, IPFC, UPQC, other FACTS Controllers: TCPAR, TCBR etc.

References:

1. N. G. Hingorani and L. Gyugyi, *Understanding FACTS*, IEEE Press, New York, 1999.
2. K.R. Padiyar, *FACT's Controllers in Transmission & Distribution,* New Age International (P) Limited, 1990.
3. V. K. Sood, *HVDC and FACTS Controllers: Applications of Static Converters in Power Systems, Kluwer academic publishers, Canada, 2004.*
4. Enrique Acha, C.R. Feurte-Esquivel and others, *Modelling and Simulation in Power Networks,* Wiley, 2004.

EE 21322 Advanced Energy Management **FIRST SEMESTER (E-I)**

Energy Efficiency and Auditing: Energy Scenario, Energy Resources, Energy Sector Reforms & Restructuring, Energy Security, Energy Conservation Act and its features, Energy Conservation, Energy Audit, Energy Bench Marking, Maximizing System Efficiencies, Energy Audit Instruments, Duties and Responsibilities of Energy Managers and Auditors, Thermal Energy Efficiency & Audits, Electrical Energy Efficiency, Audits, Energy audit in power distribution system, Loss estimation, Use of Energy Efficient Technologies, Investment Need and Criteria, Discount rate - Simple Payback period.

Supervisory Systems: Supervisory control and data acquisition systems (SCADA), Distributed Control System used in real time power systems, SCADA and operating systems. Data loggers and data display system. Remote control instrumentation, Disturbance recorders, Area and Central Control station instrumentation, Frontiers of future power system instrumentation including microprocessor based systems, sequence of events recording (SOE), Dynamic Data Exchange (DDE) module, Energy management system (EMS), substation RTU, RTDS system, Introduction to load forecasting, importance, classification-(span-wise), electricity load profiles, application of load forecasting, accurate load forecasting, deregulation, standards, performance measures, types of electricity load forecasting: Daily load profile, peak load forecasting

Energy Cost & Load Management: Economic aspects, demand side load management, energy conversion, fuel switching and load smoothing by peak clipping, valley filling, load shifting and load shading, etc. role of utility planning, motivating tariff, peak time and off-peak time. Marketing of power, Strategies for electricity bill reduction.

References:

1. Albert, Plant Engineers & Managers G*uide to Energy Conservation*, The Fairmont press,2011
2. Wayne C. Turner, *Energy management handbook*, John Wiley and Sons,2007
3. NPC energy audit manual and reports, 2009.
4. Cape Hart, Turner and Kennedy, *Guide to Energy Management*, 2008.
5. Cleaner Production – *Energy Efficiency Manual for GERIAP, UNEP, Bangkok* prepared by National Productivity Council, 2006.
6. M. K. Lahiri, *Saving of Electricity by System Management*, Lahiri Publication,
7. Turner, W. C: *Energy Management Handbook*, 5th Edition, 2004

EE 21323 EHV Transmission Technologies **FIRST SEMESTER (E-I)**

Introduction to EHV AC Transmission: Necessity of EHV AC transmission, advantages and associated problems, various EHV voltage levels, power handling capacity and line losses, mechanical consideration in line performance, cost of transmission.

Calculation of line and ground parameters: Resistance of conductors, temperature rise and current carrying capacity of conductors, calculation of inductance, capacitance of bundle conductors, calculation of sequence inductance and capacitance, surface voltage gradients on conductor and distribution of voltage gradients on subconductor of the bundle.

Corona effect in EHV system and Audible noise: Calculation of corona loss, charge-voltage diagram and corona loss, attenuation of travelling waves due to corona, Generation & characteristics of AN, Day Night AN level, radio interference.

Overvoltages in EHV system caused by switching: Types of overvoltage, overvoltages due to low inductive and capacitive current, calculation of switching surges for lumped and distributed parameter lines.

Design of EHV AC lines: Design of EHV lines based upon steady state limits, various design factors.

HVDC Transmission: Layout/Arrangement of substation, Equipments; converter transformer arrangement, converters, filters, etc. LCC and VSC converters, Multi-terminal HVDC system and its applications.

References:

1. R. D. Begamudre, EHVAC Transmission Engineering, New Age International (P) Ltd.
2. K. R. Padiyar, HVDC Power Transmission *System,* Wiley Eastern Limited, New Delhi. Second Edition, 1990.

EE 21301 Optimization Techniques **FIRST SEMESTER (E-I)**

Classical optimization techniques: Single variable optimization, multivariable optimisation with constraints and without constraints, necessary and sufficient conditions.

Linear programming (LP): Two variable problems-graphical solutions, formulation of LP problems in more than two variables, standard form, Simplex algorithm, special cases-2 phase's method, Big-M method, duality and dual LP problems. Application of LP in Transportation problem-balanced and unbalanced transportation problems. Use of North West corner rule, least cost method, Vogel approximation method. Assignment problems- Hungarian method.

Non-linear programming (NLP): Philosophy of numerical methods, search methods for one dimensional problems- Fibonacci and Golden section methods. Unconstrained and constrained optimization, univariate method , Pattern search method , Steepest descent method, cutting plane method , penalty function method, basic idea of dynamic programming.

Evolutionary algorithms (EA): Genetic algorithm, particle swarm optimisation, Tabu search, simulated annealing and ant colony optimization, Multi objective optimization using EA, Pareto solutions.

Reference:

1. Rao, S.S., Engineering Optimization: Theory and Practice. New York: Wiley. 2009
2. Deb, Kalyanmoy, Multiobjective Optimization using Evolutionary Algorithms. New York; Wiley. 2002
3. Liu G. P., Yang J. B. and Whidborne, J. F. MultiobjectiveOptimizatiion and Control. PH I. 2008
4. Belegundu, A. D., Chandrupatla, T. R., Optimization Concepts and Applications in Engineering. Pearson Education (Singapore). 2003
5. Rardin, R. L., Optimization in Operation Research. Prentice-Hall. 1999
6. Schirisieer A, Theory of linear and integer programming, John Wiley and Sons1986
7. Leunberger D, Linear and Nonlinear programming, Add. Wesley, 1984

EE 21324 Power Quality and Mitigation **FIRST SEMESTER (E-II)**

Introduction: IEC and IEEE Definition- sag, swell, harmonics, flicker, voltage imbalance, frequency deviation etc.

Voltage variations: Voltage sags, short interruptions, flicker-longer duration variations sources, range and impact on sensitive circuits-standards, solutions and mitigations, equipment and techniques

Sources of poor power quality: Non-linear loads, arcing devices, load switching, motor startup, etc

Analysis of power quality signals: Processing of Stationary signals, Processing of Non Stationary Signals, Statics and Variables, Quantitative analysis of harmonics voltage and currents, Characterization of Power quality Events, Event classification, Event statistics, Relevant standards.

Sources of harmonics: Standards, harmonics current sources; single phase rectifiers, three phase rectifiers, switching converters, harmonic current effect; IEEE 519, resonance, calculation and simulation, harmonic power flow, mitigation and control techniques, filtering, passive and active, capacitor banks and power electronics based solutions, Analysis of harmonics using Fourier techniques, Relevant standards.

References:

1. M. H. J. Bollen, *Understanding Power Quality Problems Voltage sags and Interruptions, Wiley, 2010*
2. M. H. J. Bollen, Irene, Yu.HuaGu, *Signal Processing of Power Quality Disturbances,A John Wiley & Sons, Inc., Publication ,2006*
3. C. Sankaran, *Power Quality*, CRC Press, 2002.
4. Arrillaga, J, Watson, N.R., Chen, S., ‘Power System Quality Assessment’, Wiley, New York,2000.
5. Heydt, G.T., ‘Electric Power Quality’, Stars in a Circle Publications, Indiana,2ndedition 1996.

EE 21325 Renewable Energy & Grid Integration **FIRST SEMESTER (E-II)**

Wind energy conversion systems, Wind turbines, Turbine characteristics, Various electrical generators, Induction generators, doubly-fed induction generator, Synchronous generator and permanent magnet synchronous generator (PMSG), Power conversion through power electronics converters, Maximum Power point tracking (MPPT), Controlled rectifiers and DC-DC converters for MPPT, Voltage source inverters, Modelling and control of WECS for grid interface, Standalone and grid interface application, Solar photovoltaic (PV) system, classifications, PV characteristics, MPPT methods, DC-DC converters and VSI, roof-top and domestic PV systems, Grid connected PV system, Fuel cells, classification and characteristics, power electronics interfaces, Hybrid systems, Other renewable sources of energy, Integration of renewable energy systems.

Components required for grid integration, Energy storage components and integration with the grids, Large energy storage technologies (MW), Grid integration issues and standards. Adequate converter topologies, tariff related to renewable energy interface.

Microgrid structure and operation.

References:

1. M. R. Patel, *Wind and Solar Power Systems*, Tailor & Francis CRC Press, USA, 2006.
2. M. H. Rashid (ed), *Power Electronics Handbook*, Academic Press, Florida, 2001.
3. Bin Wu, Yongqiang Lang, NavidZargari, *Power Conversion and Control of Wind Energy Systems*, Wiley, 2011.
4. Anaya-Lara, N. Jenkins et al, *Wind Energy Generation Modeling and Control*, Wiley, 2011.
5. B. Fox et al, *Wind Power Integration Connection and system operational aspects*, IET, London, 2007.
6. A. Ghosh and G. Ledwich, *Power Quality Enhancement using Custom Power Devices*, Kluwer Academic, 2002.
7. Ali Keyhani, Design of Smart Power Grid Renewable Energy Systems, 2nd Edition, Wiley-IEEE Press, 2016.

EE 21326 Computer Aided Power System Analysis **FIRST SEMESTER (E-II)**

Network Modelling and Power Flow I: System graph, loop, cutest and incidence matrices, y-bus formation, sparsity and optimal ordering, power flow analysis, Newton Rap son method.

Network Modelling and Power Flow II: Decoupled and fast decoupled method, formulation of three phase load flow, dc load flow, formulation of AC-DC load flow, sequential solution technique.

Analysis of three phase symmetrical and unsymmetrical faults: in phase and sequence domain, Phase shift in sequence quantities due to transformer, open circuit faults.

Stability Studies: Transient stability analysis, swing equation, stability of multimachine system using modified Euler method and Runge-Kutta method

Power System Security: Factors affecting security, State transition diagram, contingency analysis using network sensitivity method.

AC power flow method, introduction to state estimation.

References:

1. D. P. Kothari and I. J. Nagrath, *Modern Power System Analysis*, Tata McGraw Hill Publishing Co. Ltd., New Delhi, 1994.
2. HadiSaadat, *Power System Analysis*, Tata McGraw Hill Publishing Co. Ltd., New Delhi, 2002.
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 System*, John Wiley &Sons.K, 1988
5. Mahailnaos, D. P. Kothari, S. I. Ahson, *Computer Aided Power System Analysis & Control*, Tata McGraw Hill Publishing Co. Ltd., New Delhi, 1988.
6. G. T. Heydt, *Computer Analysis Methods for Power Systems*, Macmillan Publishing Company, New York, 1992.
7. L. P. Singh *Advanced Power.System Analysis and Dynamics*, New Age International Publishers, New Delhi, 2006.

EE 21308 Virtual Instrumentation **FIRST SEMESTER (E-II)**

Introduction, Virtual instrumentation (VI) advantages, Graphical programming techniques, Data flow programming , VI's and sub VI's, Structures, Arrays and Clusters, Data acquisition methods, File I/O, DAQ hardware, PC hardware: operating systems, Instrumentation buses, ISA, PCI, USB, PXI, Instrument control, Data communication standards, RS-232C, GPIB, Real time operating systems, Reconfigurable I/O, FPGA.

References

1. Jovitha Jerome,*Virtual Instrumentation Using Lab VIEW*, PHI Learning Pvt. Ltd, New Delhi, 2009.
2. S. Gupta and J. John, *Virtual Instrumentation Using Lab VIEW, Tata McGraw-Hill,* New Delhi, 2005.
3. R.H. Bishop, *Lab VIEW 7 Express Student Edition,* Prentice Hall, 2003.
4. National Instruments, *Lab VIEW User Manual, USA, 2003.*
5. National Instruments, *Lab VIEW Real Time User Manual, USA, 2001.*
6. National Instruments, *Lab VIEW FPGA Module User Manual, USA, 2004.*
7. L. Sokoloff, *Application Lab VIEW,* Prentice Hall, USA, 2003.
8. N. Ertugrul, *Lab VIEW for Electrical Circuits, Machine Drives and Labs,* Prentice Hall Professional, USA, 2002.
9. J. Essick, *Advanced Lab VIEW Labs,* Addison Wesley; 1 Edition, USA, 1998.
10. G.W. Johnsons, *Lab VIEW Graphical Programming,* McGraw-Hill Professional; 4 Edition, 2006.

EE 21333 Advanced Power System and Protection Lab **FIRST SEMESTER (E-III)**

List of Experiments

Simulation Based (Signal Processing application to Power System Protection)

1. Discrete Fourier transform algorithm and its application for extraction of fundamental phasor in Power Transmission System

2.To write and execute Mann Morrison Algorithm method for detection of fault in Transmission line

3.Kalman filter and its application for estimation of fundamental phasor for Power system relaying application

4. Classification and localization of fault in Transmission system using Neural Network

5. Sample techniques for the determination of apparent impendence with fixed window in transmission system.

6. Current transformer saturation detection and its effect on the performance of Distance Relay.

Protection issues with Distributed Generation(simulation)

7. Simulate a standard benchmark distributed system for different DG location.

8.Formulate a protection coordination problem in a standard benchmark distributed system.

9. Fault analysis in Micorgrid in gridconncted and Islanded Mode

Renewable Energy – Simulation based

10. To verify the static C_P-λ characteristics of a three bladed wind turbine

11. To simulate a given PV Array and to plot the I-V characteristics using Matlab.

12 Determination of the equivalent circuit parameters and the performance characteristics of a grid-connected induction generator

Protection -Experiment based

13. To study characteristics of over current relays; IDMT electromagnetic relay and microprocessor based relay.

14. To perform symmetrical and unsymmetrical fault in AC Network Analyzer.

15. Study the construction of the Thermal relay.ii Find operational characteristics of the relay.

iii.Determine time current characteristics of given fuse.

16. Digital Over Current Relay Setting and Relay Coordination.

17. Simulation and Implementation of Voltage Source Inverter

18. Co-ordination of over-current and distance relays for radial line protection

Renewable Energy – Experiment based

19.To demonstrate the I-V and P-V characteristics of PV module with varying radiation and temperature level. Also demonstrate the I-V and P-V characteristics of series and parallel combination of PV modules.

20. To show the effect of variation in tilt angle on PV module power. Also demonstrate the effect of shading on module output power.

21. Study of static and dynamic characteristics of wind turbine (WT) by emulating the wind turbine behaviour by means of a separately-excited DC motor using Lab VIEW and investigation of the performance of the wind turbine emulator (WTE) under the effects of:

a. Constant wind speed profile
b. Step variations in wind speed profile
c. A random wind speed profile comprising of Sudden rise, Sudden fall, A gust

EE 22361 Distribution Automation **SECOND SEMESTER (E-IV)**

Overview of Distribution System Planning – Tools for distribution system planning and design. Substation Automation – Data acquisition from field devices and supervisory control of field devices, Fault location, Fault isolation, service restoration, substation reactive power control Feeder level Automation- -Data acquisition from Field devices at feeder level, supervisory control of field devices, Fault location, Fault isolation, service restoration, Feeder reconfiguration, feeder reactive power control.Procedure to determine the best capacitor location.

Customer level Automation- automatic meter reading, Remote programming of time-of-use (TOU) meters, Remote service connect / disconnect, Automated customer claims analysis Control hierarchy and control centre architecture, SCADA, RTU's, IEDs, PLCs, Use of GPS and GIS systems for Asset/Facilities management.

Cost benefit analysis of Distribution Automation schemes, distribution automation roadmaps of prominent utilities in Europe and US, distribution automation in Indian utilities.

Note: The course shall have Demonstration/Field visit/CDs presentation, on implementation of automation/process in industries//power grid substation.

References

1. S. Mary S. Nardone, *Direct Digital Control Systems: Application Commissioning*, Kluwer, 1998.
2. Klaus-Peter Brand and others, *Substation Automation Handbook, 2010.*
3. M.K.Khedkar, G.M. Dhole, *Electric Power Distribution Automation*, University SciencePress, 2011.
4. A.S.Pabla, *ElectricPower Distribution,* TMH, 1999.

EE 22362 Reliability Engineering **SECOND SEMESTER (E-IV)**

Basic Reliability Concepts- Review; qualitative and quantitative assessment; Reliability-definitions, concepts, indices, criteria, availability, evaluation techniques, improvements, economics, monitoring and growth.

Basic Probability theory- Concepts, permutations & combinations, Venn diagrams, rules for combining probabilities, probability distributions, practical engineering concepts; Application of binomial distribution.

Network modeling and evaluation of systems- simple and complex, partially and standby redundant systems, cut-set method, tie set method, connection matrix technique, event trees, fault trees, multi failure modes.

Probability distributions in reliability evaluation; Discrete Markov chains, Continuous Markov processes; System reliability evaluations-series/parallel systems, network reduction techniques, minimal cut set/failure modes approach, common mode failures.

RLA of equipments in power system: Residual life assessment and management.

References:

1. Roy Billinton and Ronald N. Allan, Reliability Evaluation of Engineering Systems: Concepts and Techniques, Springer New York, 1992
2. B.S. Dhillon, Reliability, Quality, and Safety for Engineers, CRC Press, Florida, 2005.
3. K.K. Aggarwal, Reliability Engineering, Springer Netherlands, 1993.
4. E. Balagurusamy, Reliability Engineering, Mcgraw Hill Education, 2002.
5. D.Elmakias, New computational methods in power system reliability. Berlin: Springer, 2008.

EE 22363 HVDC Transmission **SECOND SEMESTER (E-IV)**

Introduction: Growth and developments, Comparison of AC and DC transmission, Application of DC transmission, HVDC terminals and types; Description of DC transmission system, Substation layout, Planning for HVDC transmission, Modern trends in DC transmission

HVDC converter arrangement: Analysis and waveforms of HVDC converters as rectifier and inverter, delay angle, overlap angle, Number of pulses, Choice of converter configuration, Simplified analysis of Graetz circuit, 6-pulse, 12-pulse groups and their voltage waveform, Powerfactor of converter.

HVDC Converter types: Commutation types in converters; natural and forced/circuit, current source converter (CSC) and voltage source converter (VSC), comparison between CSC and VSC, operating region, VSC-HVDC principle, PWM, capability curve.

HVDC converter control characteristics: Power flow in HVDC link, equivalent circuit, Compound converter control characteristics; constant extinction angle, constant current, constant ignition angle, positive current margin, negative current margin, Current margin control methods, Current control at rectifier, extinction angle control at inverter, Control hierarchy; bipole controller, pole controller, valve group controller, Control action after disturbance like phase distortion, AC faults, etc.

Harmonics and filters: Introduction, Generation of harmonics, Characteristic (2n±1) and non-characteristic (2n) harmonics, Harmonic cancellation via transformer connection, Design of AC filters, DC filters and their characteristics, AC harmonics filter calculations; impedance circle and polygon methods.

Multi-terminal HVDC (MTDC) systems: Configurations and applications, Future MTDC using VSC for wind-farm integration, Control methods in MTDC; slave and master, VSC-HVDC protection schemes, hand shaking method in MTDC.

References:

1. K. R. Padiyar, *HVDC Power Transmission System,* Wiley Eastern Limited, New Delhi. Second Edition, 1990.
2. Edward Wilson Kimbark, *Direct Current Transmission*, Vol.-I, Wiley Interscience, New York, London, Sydney, 1971

3. Colin Adamson and Hingorani N G, *High Voltage Direct Current Power Transmission*, Garraway Limited, London, 1960.
4. J. Arrillaga, *High Voltage Direct Current Transmission*, Peter Pregrinus, London, 1983.

EE 22351 Electric Traction and Vehicles **SECOND SEMESTER (E-IV)**

Electric Traction Services, Nature of Traction Loads, Conventional and Modern Traction Drives, Traction Motors, Tractions Drives, Braking Systems, Semiconductor Converter Controlled drives, Induction and Synchronous motor drives, VSI/CSI drives, Polyphase ac motors for traction Drives, Diesel Electric traction, Energy Conservation, Interlocking and sequencing operations and protection.

Introduction to Alternative Vehicles, Electric Vehicles, Hybrid Electric Vehicles, Electric and Hybrid, Vehicle Components, Vehicle Mass and Performance, Electric Motor and Engine Ratings, Well-to-Wheel Analysis, EV/ICEV Comparison, Electric Vehicle Market, Vehicle Mechanics, Roadway Fundamentals, Laws of Motion, Vehicle Kinetics, Dynamics of Vehicle Motion, Propulsion Power Velocity and Acceleration, Tire–Road Force Mechanics, Propulsion System Design

Plug-In Hybrid Electric Vehicle, Power train Component Sizing, Mass Analysis and Packaging, Vehicle Simulation, Battery Energy Storage, Batteries in Electric and Hybrid Vehicles, Battery Modeling, Traction Batteries, Battery Pack Management, Alternative Energy Storage, Fuel Cells, Ultra capacitors, Compressed Air Storage, Flywheels Control of AC Machines.

Power train Components and Brakes, Cooling Systems, Vehicle Supervisory Controller, Mode Selection Strategy, Modal Control Strategies

References:

1. Sandeep Dhameja,*Electric Vehicle Battery Systems*, Elsevier,First Edition, 2002
2. John Fenton & Ron Hodkinson, *Lightweight Electric/Hybrid Vehicle Design*,Elsevier Oxford, 2000.
3. Seth Leitman, Bob Brant, *Build Your Own Electric Vehicle*, McGraw Hill, Third Edition, 2013.
4. Iqbal Husain,*Electric and Hybrid Vehicles: Design Fundamentals*, CRC Press,Second Edition, 2010.
5. MehrdadEhsani, YiminGao, and Ali Emadi, *Modern Electric*, *Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory and Design*, CRC Press, Second Edition 2009.

EE 22364 Power System Planning **SECOND SEMESTER (E-V)**

Introduction: Basic principles, power system elements, structures, power system study in the perspective of various time horizon, various planning issues, role of renewable energy plants.Interconnected Systems, Research trends in PSP

Economic aspects and Optimization methods: Definition and various related terms, deregulation and constant tariff scheme, cash flow concept, economic analysis by present worth method, annual cost method, rate of return method. Importance of optimization, defining an optimization problem, problem modelling, constraints and limitations, conventional approaches: LP, dynamic programming, Newton's method, Gauss method, other conventional methods, heuristic approaches: nature inspired techniques, viz., SA, ACO, GA, PSO, etc.

Load forecasting: Relevance, various load characteristics, factors affecting the load, ISOs, Demand side management, spatial load forecasting, econometric models, time-series models, and heuristic models,

Expansion planning (basic and advanced approaches for generation, sub-station and network expansion): Basic definition, problem description, mathematical development, constraints, required data, solution algorithm for single and multi-bus generation planning.

Reactive power planning: Introduction, voltage profile, voltage stability, parameters affecting voltage profile, resources for static and dynamic reactive power. Problem description: static resource allocation and sizing, dynamic resource allocation and sizing, mathematical solution approaches.

Uncertainties and deregulated electricity market: Introduction, uncertainties due to regulated and deregulated environment, practical issues under deregulated environment, methods to deal uncertainties PSP: expected cost criterion, min-max regret criterion, Laplace criterion, VNM criterion, Hurwicz criterion.

References:

1. Hossein Seifi, Mohammad SadeghSepasian, *Electric power system planning: Issues, Algorithms and solutions*, Springer-Verlag Berlin Heidelberg 2011
2. James Momoh and LamineMili, *Economic Market Design and Planning for Electric Power Systems*, IEEE Press series on power engineering, M E Hawary (Ed.), A John Wiley & Sons, Inc., Publication, 2010

3. FawwazElkarmi and Nazih Abu-Shikhah, *Power System Planning Technologies and Applications: Concepts, Solutions,and Management,* Engineering Science Reference, IGI Global, 2010
4. Sullivan, R.L., *Power System Planning*, Heber Hill, 1987.

EE 22365 Power System Communication **SECOND SEMESTER (E-V)**

Introduction: Need of communications for the protection, control and monitoring of the transmission and distribution systems, examples include state estimation and load flow, generator dispatch, voltage and var control, outage management, and demand response.

Fundamentals of Communication Engineering: Basics of modulation and sampling; analog and digital modulation techniques; multiple access schemes; spread spectrum techniques.

SCADA: Introduction, SCADA Functional requirements and Components, General features, Functions and Applications, Benefits, Configurations of SCADA, RTU (Remote Terminal Units) Connections, Power Systems SCADA and SCADA in Power System Automation, SCADA Communication requirements, SCADA Communication protocols: Past Present and Future, Structure of a SCADA Communications Protocol, Theory of operation, installation and testing of substation LANs.

Communication Protocols for the Smart Grid: Communication data protocols such as Modbus, DNP3.0, and IEC 61850 including GOOSE and GSSE relay-to-relay messaging, Specifications, theory of operation and capabilities of RS232, RS485, 10/100 Base T and 10/100 Base F Ethernet LANs, protocols for home/building automation networks (OpenHAN, BACnet, LonWorks, and ZigBee); protocols for communication between control centers (TASE.2/ICCP); time synchronization protocols (NTP, IRIG-B, PTP).

Note: The course shall have demonstration either in the laboratory or visit to nearby power substation.

References:

1. William Stallings, *Data and Computer Communication*, PHI, 1994.
2. John Gowar, *Optical Communications Systems*, PHI, 1993.
3. Theodore S. Rappaport, *Wireless Communication*, Principles and Practice, IEEE Press; PH PTR,1996
4. K. Feher, *Wireless Digital Communications*, PHI, 1995.
5. Wood, A. J and Wollenberg, B. F, *Power Generation Operation and Control*, 2nd Edition John Wiley and Sons, 2003.
6. Green, J. N, Wilson, R, *Control and Automation of Electric Power Distribution Systems*, Taylor and Francis, 2007.
7. E. Hossain, Z. Han and H.V. Poor, *Smart Grid Communications and Networking*, Cambridge University Press, 2012.
8. John D Mc Donald, *Electric Power Substation Engineering*, CRC press, 2001.

9. A.S. Tanenbaum, *Computer Network*, 1980.
10. *Related IEEE/IEE Publications.*

EE 22366 Power System Dynamics **SECOND SEMESTER (E-V)**

Introduction General basic concept of Power System Stability, States of operation & System Security, System Dynamics Problems, Review of Classical Model, System Model, Analysis of Steady State Stability & Transient Stability.

Modeling of Synchronous Machine Synchronous Machine, Park's Transformation, Analysis of Steady State Performance, P. U. Quantities, Equivalent Circuit of Synchronous Machine

Excitation systems & Prime Mover Controllers: Simplified Representation of Excitation

Control, Excitation systems, Modeling, Std. Block Diagram, State Equations, Prime Mover Control System, Transmission Line & Load Modeling

Dynamics of Synchronous Generator Connected to Infinite Bus System Model, Synchronous Machine Model, System Simulation, Consideration of other Machine Models including SVC Model.

Small signal Stability -Single and multi-machine system, Damping and Synchronizing torque Analysis, Power System Stabilizers.

Transient Stability and Voltage Stability Evaluation and Simulation, application of energy

functions for direct stability evaluation, TS controllers. Voltage Stability: Introduction, affecting factors, its analysis.

References:

1. K. R. Padiyar, Power System Dynamics – Stability & Control, BS Publications, 2002.
2. P.Sauer&M.A.Pai, Power System Dynamics & Stability, Prentice Hall, 1997.
3. PrabhaKundur, Power System Stability and Control, Tata McGraw Hill, 1994.
4. P.M Anderson, F. Fouad, Power System Control and Stability, Iowa StateUniversity Press, Ames, Iowa, 1978

EE 22356 Active Power Conditioning **SECOND SEMESTER (E-V)**

Introduction: Distribution and Transmission system, Power electronics based nonlinear loads, Power Quality issues, Custom Power (CP) and FACTS devices

Power Quality Characterization and Analysis: Load power factor, Harmonic distortion indices, transients, unbalancing and symmetrical components, Voltage sag/swell and flicker indices, Power acceptability curves, Harmonic distortions limits: IEEE 519, IEC standards

Conventional Methods of Compensation: Load balancing, Capacitor banks, Higher pulse converter, Transformer connections, Harmonic filter design, Resonance effect, Frequency domain analysis

Reference Current Generation: Instantaneous PQ theory, Instantaneous symmetrical components, Moving average, Low pass and High pass filters, phase-locked loop (PLL)

Hybrid and Active Power Filters: Shunt, Series and Shunt-series active power filters, structure &control of APFs, Combination of active and passive hybrid power filters.

DSTATCOM: Structure, Modeling and Control, Voltage and Current control mode, Self supported structure, dc link voltage control loop

DVR: Structure, Modeling and Control, External energy storage and Rectifier supported structure, pre-sag reference angle and phase jumps

UPQC: Structure, Modeling and Control

Distributed Generation: Solar and Wind power conversion, Converter structures, Standalone and Grid Interface applications and control

References:

1. A. Ghosh and G. Ledwich, *Power Quality Enhancement using Custom Power Devices*, Kluwer Academic Publisher, Boston, MA, 2002.
2. G. J. Walkileh, *Power Systems Harmonics*, Springer Verlag, New York, 2001.
3. IEEE Standard 519-1992, IEEE recommended practices and requirements for harmonic control in electrical power systems, 1992.
4. R. C Dugan , S. Santoso, M. F. McGranaghan and H. W. Beaty, *Electric Power System Quality*, McGraw-Hill, New York, 2003.

5. M. H. Rashid, *Power Electronics Handbook*, Elsevier, Third Edition, 2011.
6. J. Stones, and A. Collinson, *Power quality*, Power Engg. Journal, vol. 15, no.2, pp. 58-64, April 2001.
7. J. K Phipps, *A Transfer function approach to harmonic filter design*,IEEE Industry Application Magazine, pp. 68-82, March/April, 1997.
8. F. Z. Peng, *Application issues of active power filters*, IEEE Ind. Applicat. Mag., vol.4, no.5, pp.21-30, Sept./Oct. 1998.

List of Experiments

1. Simulate Static VAR Compensator and STATCOM using MATLAB/PSCAD software & Plot the characteristics
2. Simulate & study on transients in Thyristor Switched Capacitor (TSC) and find favourable instant for switching the capacitor.
3. Simulate & study on transients in Thyristor Controlled Capacitor and plot the characteristics for various firing angles.
4. Simulate firing angle control of Thyristor Controlled capacitor using Model in MATLAB/PSCAD software and tabulate the theoretical and simulation values.
5. Simulate the D-STATCOM and plot the current and voltage waveforms using MATLAB/PSCAD software.
6. Simulate the basic circuit of Series Compensation and plot the current and voltage waveforms for the series load.
7. To design and simulate the single phase series compensation network using Matlab Software.
8. Design and simulate basic Thyristor Controlled Series capacitor using Model in MATLAB/PSCAD software and Plot the voltage and current waveforms.
9. To study small signal and transient stability of one machine connected to infinite bus system.
10. To study small signal and transient stability of multi-machine (3 bus, 9 bus) power system.
11. To implement load frequency regulation in two area thermal-thermal (reheat) power system with integral and optimal controller design.
12. To study voltage stability characteristic of two area with SVC.
13. Develop the state-space representation, find the eigenvalues, left eigenvectors, and participation factors fora regulator system.
14. Simulate 3rd order model of synchronous machine with IEEE Type 1 excitation system.
15. Simulate SMIB system with 3rd order model of synchronous machine, i.e. Heffron-Phillips model. Find the eigenvalues with exciter included, with exciter and PSS included.
16. Simulate in Simulink the AVR system of a generator has the following parameters with step disturbance. Obtain the value of exciter amplifier gain for which the response becomes unstable.Find out the time domain performance specifications, namely, peak time, rise time,

settling time and percent overshoot.Also find out closed loop transfer function and plot the poles and zeros.

17. To simulate in Simulink the Excitation System Stabilizer with PID Controller step disturbance. Find out the time domain performance specifications, namely, peak time, rise time, settling time and percent overshoot. Also find out closed loop transfer function and plot the poles and zeros.
18. To plot the swing equation curve by using point to point method for a power system. Plot swing curves with fault cleared by simultaneous opening of breakers at both ends of the line at 3 cycles and 6 cycles after the occurrence of fault. Also plot the swing curve over the period of 0.5sec if the fault is sustained.
19. To study over-voltages resulting from switching of transmission lines and limitingthem by sing ZnO arresters.