Semester-I

EEL 2101 POWER SYSTEM DYNAMICS

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Aware of the power system stability problems.
- Understand the small and large disturbance stabilities.
- Know the modeling of synchronous machines and power system components.
- Understand the different power system stability analyses.
- Measures are taken to improve power system stability.

1. Load Flow Analysis:

Newton Raphson & Fast decoupled method (FDM)

Lectures: 2

2. Optimum Power Flow (OPF):

Formulation of OPF, LP-based gradient, and Newton's method. Bus Incremental Cost (BIC).

Lectures: 2

3. Introduction to Power System Stability:

Basic concepts and definitions; rotor angle stability, voltage stability and voltage collapse, Mid-term, and long-term stability; classification of stability.

Lectures: 4

4. Analysis of Stability: Voltage Stability:

Basic concept, voltage collapse, prevention of voltage collapse mechanism, voltage stability analysis, effects of excitation system, power system stabilizer.

Lectures: 4

5. Small Signal Stability:

The fundamental concept of stability of the dynamic system, small signal stability of single machine infinite bus system, small signal stability of multi-machine systems, characteristics of small signal stability problems.

Lectures: 4

6. Transient Stability:

Analysis using Numerical Integration Techniques, simulation of power system dynamics response, and case study of transient stability of a large system.

Lectures: 6

7. Synchronous Machine Representation in Stability Studies:

Simplifications for large-scale studies; Simplified model with amortisseurs neglected; constant flux linkage models.

Lectures: 7

8. Modeling of Excitation and Prime Mover Systems:

Elements of Excitation System; Types of Excitation System; modeling of excitation system; Hydraulic turbine and Governing System Modeling; Steam turbine and governing systems.

Lectures: 7

Text Books:

1. P.Kundur, Power System Stability and Control, McGraw Hill Inc, New York,1995.
2. K.R.Padiyar, Power System Dynamics, Stability & Control, 2nd Edition, B.S. Publications, Hyderabad, 2002.

3. Allen J Wood & Bruce Wollenberg, POWER GENERATION OPERATION & CONTROL, 2ND ED, wiley publisher

Reference Books:

1. P.Sauer & M.A.Pai, Power System Dynamics & Stability, Prentice Hall, 1997.

EEL 2102 ADVANCED POWER CONVERTERS

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Explain the types of AC to DC converters and their working principle with different loads.
- To discuss the techniques for the design and analysis of dc-dc converters, Resonant Pulse Inverters, and multilevel inverters
- Evaluate the performance parameters of resonant inverters
- Discuss the types, topologies operation, and analysis of multilevel inverters.
- Discuss residential, Industrial, and Electrical utility applications of power electronic devices.

1. AC-DC Converters:

Principle of operation of single phase and three phases half wave, half controlled, full controlled converters with R, R-L and RLE loads, effects of freewheeling diodes and source inductance on the performance of converters. External performance parameters of converters, techniques of power factor improvement, single phase and three phase dual converters.

Lectures: 6

2. DC-DC Converters:

Buck, Boost, Buck-boost, and Cuk converters – topology, voltage transfer ratio, current and voltage waveforms, voltage and current ripple, modeling in the State Space Method. Linear power supplies, an overview of switching power supplies, DC-DC converters with Electrical isolation (Flyback, Forward, Push-pull, Half and Full bridge converter), Control of Switch Mode DC Power Supplies.

Lectures: 8

3. Resonant Pulse Inverters:

Introduction. Series Resonant Inverters, Frequency Response of Series Inverters, Parallel Resonant Inverters, Voltage Controlled Resonant Inverters, Class E Resonant Inverter, Class E Resonant Rectifier, Zero – Current Switching (ZCS) Resonant Converters, Zero Voltage Switching Resonant Converters (ZVS), Comparison between ZCS and ZVS Resonant Converters, Two Quadrant ZVS Resonant Converters, Resonant DC – Link Inverter.

Lectures: 7

4. DC-AC converters:

Single-phase and three-phase bridge inverters, PWM switching scheme, unipolar and bipolar switching scheme, space vector modulation (SVPWM), Reduction of harmonics, and Output Voltage Control.

Lectures: 7

5. Multilevel Inverters:

Introduction, Multilevel Concept, Types of Multilevel Inverters, Diode -Clamped Multilevel Inverter, Flying – Capacitors Multilevel Inverter. Cascaded Multilevel Inverter, Applications, Features of Multilevel Inverters, Comparison of Multilevel Converters.

Lectures: 4

6. Residential and Industrial Applications:

Introduction, Residential Applications, Industrial Applications. Electrical Utility Applications: Introduction, High Voltage DC Transmission, Static VAR Compensators, Interconnection of Renewable Energy Sources and Energy Storage systems to the Utility Grid, Active Filters.

Lectures: 4

Prescribed Text Books

1. Ned Mohan, T.M. Undeland and William P. Robbins, Power Electronics: Converters, Applications, 3rd Edition, John Wiley & Sons, 2009.
2. M. H. Rashid, Power Electronics-Circuits, Devices and Applications, 3rd Edition, PHI, 2005
3. C.WLander, Power Electronics, McGraw-Hill book company, 1981
4. Eacha, TJE miller, power electronics control of an electrical system, newness
5. HW Whittington, switch mode power supply, design and construction, research studies press.

Additional Readings

1. S. B. Dewan &A. Straughen, Power Semiconductor Circuits, John Wiley & Sons, 1975
2. B.K Bose, Modern Power Electronics and AC Drives, Pearson Education, 2003.

EEL 2103 NONCONVENTIONAL AND DISTRIBUTED ENERGY SOURCES

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understanding of nonconventional energy sources
- Knowledge of solar photovoltaic power generation
- Power generation from wind energy
- Power generation from other nonconventional energy sources
- Understanding of distributed energy sources

1. Nonconventional Energy Sources:

World energy resources, Indian energy scenario, environmental aspects of energy utilization, nonconventional energy resources and their importance.

Lectures: 4

2. Solar Energy:

Availability of solar energy, nature of solar energy, solar cell energy conversion, efficiency, characteristics, the effect of variation of solar insolation and temperature, losses, components of PV systems, solar PV power plants, photo thermal systems, F chart method, φ–F chart method, utilizability modeling & simulation of solar energy systems, life cycle analysis of solar energy system.

Lectures: 8

3. Wind Energy:

Wind resource assessment, power conversion technologies, wind power estimation techniques, principles of aerodynamics of wind turbine blade, wind mechanics, power content, class of wind turbines, various aspects of wind turbine design, wind turbine generators: induction, synchronous machine, constant V & f and variable V & f generations.

Lectures: 8

4. Alternate Energy Sources:

Hydrogen as a renewable energy source, a source of hydrogen, and fuel for vehicles. Classification of hydel plants, the concept of micro hydel, MHP plants: components, design and layout, turbines, efficiency, status in India. Bio-Mass, Bio-Gas, Tide, and Wave Energies Basic concepts and principles of operation.

Lectures: 6

5. Distributed Energy Sources:

Benefits and limitations; classification of small generating systems, electric equivalent circuits of fuel cells, solar cells, micro-turbines, reciprocating engines, wind turbines, and gas turbines, effects of renewable energy into the grid, supply guarantee, power quality, stability, intentional and unintentional islanding, power converter topologies for grid interconnection, inverter modeling, control of grid-interactive power converters, synchronization and phase locking techniques, current control, and recent trends in DG interconnection.

Lectures: 10

Text Books

1. Andrews J, Jelley N, Energy Science, Oxford University Press, 2010
2. Fang Lin Luo, Hong Ye, Renewable Energy Systems: Advanced Conversion Technologies and Applications, CRC Press, Taylor & Francis Group.
3. H Lee Willis, Walter G Scott, Distributed Power Generation, Planning & Evaluation, CRC Press Taylor & Francis Group.

Reference Books

1. Remus Teodorescu, Marco Liserre, Pedro Rodr´ıguez, Grid Converters for Photovoltaic and Wind Power Systems, John Wiley & Sons.
2. B H Khan, Non-Conventional Energy Resources, Tata McGraw-Hill Education.

EEL 2104 ADVANCED POWER SYSTEM PROTECTION

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand advanced topics of power system protection.
- Familiarize yourself with industrial practices.

1. Static Relays:

Advantages of static relays – Basic construction of static relays – Level detectors – Replica impedance – Mixing circuits – General equation for two input phase and amplitude comparators -Duality between amplitude and phase comparators. Amplitude Comparators: Circulating current type and opposed voltage type – rectifier bridge comparators, Direct and Instantaneous comparators.

Lectures: 4

2. Phase Comparators:

Coincidence circuit type – block spike phase comparator, techniques to measure the period of coincidence – Integrating type – Rectifier and Vector product type – Phase comparators. Static Over Current Relays: Instantaneous over-current relay – Time over-current relays-basic principles – definite time and Inverse definite time over-current relays.

Lectures: 8

3. Static Differential Relays:

Analysis of Static Differential Relays – Static Relay schemes – Duo bias transformer differential protection – Harmonic restraint relay. Static Distance Relays: Static impedance-reactance – MHO and angle impedance relay-sampling comparator – realization of reactance and MHO relay using sampling comparator.

Lectures: 8

4. Multi-Input Comparators:

Conic section characteristics -Three input amplitude comparator – comparator-switched distance schemes – Poly phase distance schemes – phase fault scheme – three-phase scheme – combined and ground fault scheme. Power Swings: Effect of power swings on the performance of distance relays – Power swing analysis – Principle of out-of-step tripping and blocking relays – effect of line and length and source impedance on distance relays.

Lectures: 8

5. Microprocessor-Based Protective Relays:

(Block diagram and flowchart approach only) – Over-current relays – impedance relays – directional relay – reactance relay – Generalized mathematical expressions for distance relays -measurement of resistance and reactance – MHO and offset MHO relays – Realization of MHO characteristics – Realization of offset MHO characteristics – Basic principle of Digital computer relaying.

Lectures: 8

Text Books:

1. Badri Ram and D. N. Vishwakarma, “Power system protection and Switchgear “, TMH publication New Delhi 1995.

Reference Books:

1. T.S. Madhav aRao , “Static relays”, TMH publication, second edition, 1989.
2. Protection and Switchgear, Bhavesh Bhalja, R. P. Maheshwari, Nilesh G. Chothani, Oxford University Press.
3. Electrical Power System Protection, C. Christopoulos and A. Wright, Springer International.

EEP 2101 ADVANCED POWER SYSTEMS LAB

L-T-P: 0-0-3 **Credit: 1.5**

Course Outcomes:

- To understand the experimental determination of various parameters used in power system area and to analyse the performance of transmission line with and without compensation.
- After the Completion of lab they will understand procedure for determination of various parameters used in power system as well as performance of transmission line.

List of Experiments

1. Study on ac-dc load flow.
2. Study of symmetric & and asymmetric faults in the Transmission line.
3. Load flow analysis of two bus systems with STATCOM
4. Transient analysis of a two-bus system with STATCOM.
5. Available Transfer Capability calculation using an existing load flow program.
6. Study of variable speed wind energy conversion system with DFIG
7. Study of variable speed wind energy with PMSG.
8. Computation of harmonic indices generated by a rectifier feeding an R-L load.
9. Study of Power transfer through a transmission system
10. Study of various protection schemes in a transmission line.

EEP 2106 MODELING & SIMULATION LAB.

L-T-P: 0-0-3 **Credit: 1.5**

Course Outcomes:

- Able to use MATLAB, PSIM, and PSCAD.
- Able to program the Modeling and Simulation of various Electrical circuits.
- Exposed to the use of Graphical User Interfaces like SIMULINK etc., for Modeling and simulation.

List of Experiments

1. To design the gain parameters for a PI and PID controller for a SISO system in MATLAB SIMULINK.
2. To design a Buck- Boost converter in continuous, discontinuous, and critical conduction modes in PSPICE/PSIM.
3. To find the load flow parameters using Newton-Raphson Method in MATLAB.
4. To fast decoupled load flow in MATLAB.
5. To find DC load flow using ETAP.
6. To find economic dispatch problems considering transmission loss in MATLAB.
7. Study of limit cycle analysis of Non-linear system.
8. To model an alternator in SIMULINK.
9. To design an overall system comprising generation transmission and distribution in SIMULINK.
10. Design of State feed back control of DC motor.
11. Design of State feedback control inverted pendulum and EMLS. 12. Transient Study of Induction Motor.

Prescribed Text Book

1. K. Ogata, Modern Control Engineering, Pearson Education, 2009
2. M. Gopal, Digital Control and State Variable Methods, Tata McGraw Hill, 2003
3. D.P. Kothari & J.S Dhillon, Power System Optimization, 2nd Edition, PHI, 2005.
4. M. H. Rashid, Power Electronics-Circuits, Devices and Applications, 3rd Edition, PHI, 2005
5. Mathwork, ETAP, ORCAD-PSPICE manual

Semester-II

EEL 2201 POWER SYSTEM INTERCONNECTION AND CONTROL

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understanding of load frequency control
- Knowledge of unit commitment
- Coordination of hydro and thermal power plants
- Power system security analysis
- Understanding of state estimation and load forecasting

1. Load Frequency Control:

Basics of speed governing mechanism, control area concept, load frequency control of a single and two area system, tie-line bias control of single and two area system, static and dynamic response of single and two area system, integration of economic dispatch control with LFC.

Lectures: 8

2. Unit Commitment:

Statement of Unit Commitment problem – constraints, spinning reserve, thermal unit constraints, hydro constraints, fuel constraints, and other constraints, unit commitment Solution methods – priority list methods -forward dynamic programming approach.

Lectures: 5

3. Hydro-thermal Coordination:

Hydroelectric plant models, short-term hydrothermal scheduling problem - gradient approach, hydro units in series, pumped storage hydro plants, hydro-thermal scheduling using Dynamic programming, and hydro scheduling using linear programming.

Lectures: 6

4. Power System Security:

Factors affecting power system security, Security analysis, security assessment, contingency analysis, algorithm to determine system security following contingency analysis procedure, security assessment using ac power flow model, security analysis using the concept of the performance index.

Lectures: 6

5. State Estimation:

Methods of state estimation – least square and weighted least square estimation, bad data detection, and suppression of bad data.

Lectures: 5

6. Load forecasting:

Load forecasting techniques, estimation of average and trend terms, estimation of periodic components, estimation of stochastic part of load – time series approach, prediction of deterministic load.

Lectures: 6

Text Books:

1. Robert H. Miller, James H. Malinowski, 'Power system operation', Tata McGraw-Hill, 2009
2. Allen J. Wood, Bruce F. Wollenberg, 'Power Generation, Operation and Control', Wiley India Edition, 2nd Edition, 2009.
3. D. P. Kothari and I. J. Nagrath, Power System Engineering, McGraw-Hill, 2011
4. T J Miller, 'Reactive Power Control in Electric Systems', Wiley, 1982.

References:

1. Abhijit Chakrabarti and Sunita Halder, Power System Analysis, Operation and Control, PHI.
2. O. I. Elgerd Electric Energy system Theory - An Introduction Tata McGraw-Hill, 2002

EEL 2202 ENERGY STORAGE SYSTEMS

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the characteristics of energy storage devices
- Model and simulate the characteristics of energy storage systems
- Explore the possibilities of deployment of energy storage systems in smart cities and electric vehicles.
- Evaluate and suggest an efficient storage system in electric transportation.

1. Introduction

Impacts and requirements of Electrical Energy Storage system, Classification of Energy Storage Systems, Energy costs, and load analysis. Grid Applications of Energy Storage systems, Ancillary Services from Energy storage. Traditional generation costs and optimizations. Power flow and energy balance in a wide area network. Economics of energy and power tied to electrical rates and demand response.

Lectures: 12

2. Electrochemical Energy Storage

Batteries: Introduction to battery storage including lead acid, lithium-ion, flow, and emerging battery technologies. Comprehensive analysis of design considerations and application-specific needs. Impacts on system cost in terms of the life cycle, environment, and reliability of the end solutions.

Ultra-Capacitors: Introduction to ultra-capacitors including operation, applications, and emerging technologies. Topics include the usage of mobile applications and proximity to renewable energy sources. Discussion of primary target market usage in today's energy and power sectors.

Super Conducting Magnetic Energy Storage (SMES): Introduction to Super Conducting Magnetic Energy Storage (SMES) operation, theory of usage, and emergent research, with a focus on large utility-scale energy storage facilities.

Mobile and Fixed Energy Storage: Advantages and disadvantages of mobile vs. stationary energy storage, with a focus on vehicle-to-grid applications and opportunities to leverage existing and emergent technology to provide additional grid support functions. Concept of time-of-day metering for storage planning and management.

Lectures: 12

3. Mechanical Energy Storage

Pumped Hydro: Models for pumped hydro capacity and availability, System cost, capacity, conversion efficiency, and siting.

Com

pressed Gas: Compressed gas storage technologies as bulk energy storage. Models for compressed gas capacity, efficiency, availability, System cost, capacity, conversion efficiency, siting, and associated barriers, and possible applications in carbon capture and appropriation.

Flywheel: Flywheel energy storage system, Models for flywheel capacity, availability, efficiency, and self-discharge, Applications in transportation, uninterruptible power supply (UPS), pulse power, and bulk storage, Selection and design of flywheels for safety and availability in various applications.

Thermal: Introduction to thermal storage in residential and utility-scale applications including molten salts, cold reservoirs, and phase change materials, Analysis of design considerations, material selection, and application-specific constraints, Applications in renewable energy at utility-scale solar and geothermal power production.

Lectures: 12

Text Books:

1. S. Chowdhury, S. P. Chowdhury, P. Crossley, "Microgrids and Active Distribution Networks", IET Power Electronics Series, 2012.
2. Ali Keyhani Mohammad Marwali and Min Dai, Integration and Control of Renewable Energy in Electric Power System, John Wiley publishing company, 2nd Edition, 2010.

Reference Books:

1. Mini S Thomas and J. D MacDonald, " Power System SCADA and Smart Grid," CRC Press, 1st Edition, 2015.
2. N. Hatziargyriou, "Microgrids Architecture and control", Wiley-IEEE Press Series, 1st Edition 2013.
3. D. Mah, P. Hills, Victor O.K. Li, R. Balme, "Smart Grid Applications and Developments," Springer- Verlag London, 1st Edition, 2014.
4. J. Ekanayake, N. Jenkins, K. Liyanage, J. Wu, A. Yokoyama, "Smart Grid: Technology and Applications," John Wiley & Sons, 1st Edition, 2015.

EEL 2203 FLEXIBLE AC TRANSMISSION SYSTEM (FACTS)

L-T-P: 3-0-0 **Credit: 3**

1. Introduction to Flexible Alternating Current Transmission System (FACTS):

Fundamentals of ac power transmission, transmission problems and needs, Emergence and advantages of FACTS technology in transmission system, Types of FACTS controller, Application of FACTS controllers in Distribution System.

Lectures: 3

2. **Power Flow Control:**

   Theory and implementation of Power Flow Control Concepts, Analysis of uncompensated AC Transmission line, Passive reactive power compensation: Effect of series and shunt compensation at the mid-point of the line on power transfer.

   Lectures: 3

3. **Static VAR Compensation:**

   Analysis of SVC, Configuration of SVC, SVC Controller, Voltage Regulator Design, Harmonics and Filtering, Protection Aspects, Application of SVC

   Lectures: 6

4. **Series and Shunt Compensation:**

   Principles of shunt compensation, Variable Impedance type & switching converter type-Static Synchronous Compensator (STATCOM) configuration, characteristics and control, Basic concepts of controlled series compensation, Principles and operation of static series compensation using GCSC, TCSC and TSSC, applications, Static Synchronous Series Compensator (SSSC)

   Lectures: 8

5. **Static Voltage and Phase Angle Regulators:**

   Principles of operation-Steady state model and characteristics of a static voltage regulators and phase shifters power circuit configurations, Power-flow control and improvement of stability by phase angle regulator, Introduction to Thyristor Controlled Voltage and Phase Angle Regulators (TCVR and TCPAR)

   Lectures: 5

6. **UPFC & IPFC**

   Principles of operation and characteristics, independent active and reactive power flow control, comparison of UPFC with the controlled series compensators and phase shifters, Applications of UPFC. Interline Power Flow Controller (IPFC), basic operating principles and characteristics, Applications of IPFC.

   Lectures: 5

7. **Modeling of FACTS devices** **Lectures: 6**

Text Books

1. K.R.Padiyar, FACTS controllers for transmission and Distribution systems, New Age international Publishers.
2. Y.H. Song and A. T. Johns, Flexible ac transmission systems (FACTS), Institution of Electrical Engineers Press, London.

Additional Readings

1. R. M. Mathur and R. K.Varma, Thyristor - based FACTS controllers for Electrical transmission systems, IEEE press, Wiley Inter science.

EEP 2202 POWER AND ENERGY SYSTEMS LAB

L-T-P: 0-0-3 **Credit: 1.5**

Course Outcomes:

- Understand the operation and behavior of solar PV panel
- Effect of load on solar panel
- Analysis of wind turbine output
- Analysis of distributed energy system
- Analysis of load frequency control in one and two area system

List of Experiments

1. To determine the efficiency of Solar PV panels at different irradiance levels.
2. To determine the efficiency of a wind turbine for different wind speeds.
3. Test the Capabilities of the Hydrogen Fuel Cells and Capacitors.
4. Effect of Temperature on Solar Panel Output.
5. Variables Affecting Solar Panel Output.
6. Effect of Load on Solar Panel Output.
7. Wind Turbine Output: The Effect of Load.
8. Test the Capabilities of Solar Panels and Wind Turbines.
9. Study of distributed energy systems.
10. Analysis of grid-connected distribution system.
11. Simulation of one area load frequency control model.
12. Simulation of two area load frequency control model.

Text Books

1. Fang Lin Luo, Hong Ye, Renewable Energy Systems: Advanced Conversion Technologies and Applications, CRC Press, Taylor & Francis Group.
2. B H Khan, Non-Conventional Energy Resources, Tata McGraw-Hill Education.

Reference Book

1. MATLAB simulation manual.

LIST OF DEPARTMENTAL ELECTIVES: for SEMESTER- I

EEL XX11 HVDC TRANSMISSION

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Apply scientific and engineering principles to analyze and design the converter.
- Recognize harmonics in HVDC transmission.
- Appropriately analyze the control strategy of the HVDC system
- Identify the converter faults and apply a protection scheme for faults

1. Introduction:

Introduction of DC power transmission technology, comparison of AC and DC transmission, description of DC transmission system, modern trends in DC transmission.

Lectures: 4

2. Analysis of HDVC converters:

Choice of converter configuration, simplified analysis of Graetz circuit, converter bridge characteristics, Characteristics of a twelve pulse converter, detailed analysis of converters.

Lectures: 8

3. Control of HVDC converter and systems:

Rectifier control, compounding of rectifiers, power reversal of DC link, voltage-dependent current order limit (VDCOL) characteristics of the converter, inverter extinction angle control, pulse phase control, starting and stopping of DC link, constant power control, the control scheme of HVDC converters.

Lectures: 8

4. Harmonics and filters:

Generation of harmonics by converters, characteristics of harmonics on the DC side, characteristics of current harmonics, characteristic variation of harmonic currents with a variation of firing angle and overlap angle, the effect of control mode on harmonics, non-characteristic harmonic. Harmonic model and equivalent circuit, use of a filter, filter configuration, design of band-pass and high pass filter, protection of filters, DC filters, filters with voltage source converter HDVC schemes.

Lectures: 6

5. Fault and protection schemes in HVDC systems:

Nature and types of faults, faults on the AC side of the converter stations, converter faults, faults on the DC side of the systems, protection against over currents and voltages, protection of filter units.

Lectures: 4

6. Multi-terminal HVDC systems:

Types of multi-terminal (MTDC) systems, parallel operation aspect of MTDC. Control of power in MTDC. Multilevel DC systems. Power upgrading and conversion of AC lines into DC lines, Parallel AC/DC systems, FACTS, and FACTS converters.

Lectures: 6

Text Books

1. S. Kamakshaiah& V. Kamaraju, HVDC Transmission, Tata McGraw hill education.
2. K.R.Padiyar, HVDC Power transmission system, Wiley Eastern Limited.
3. J. Arrillaga, Peter Pregrinu, High Voltage Direct Current Transmission

Reference Books

1. A. Chakraborty, D.P. Kothary, A.K. Mukhopadhyay, The Performance, Operation, and Control of EHV Power Transmission Systems, Wheeler Pub.
2. Rakosh Das Begamudre, Extra High Voltage AC Transmission Engineering, New Age International (P) Ltd.
3. Colin Adamson and N.G.Hingorani, High Voltage Direct Current Power Transmission, Garraway Limited, London

EEL XX12 OPTIMIZATION TECHNIQUES

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Acquire a systematic understanding of optimization techniques.
- Understanding in detail the problem formulation and the solution approaches.
- Understanding a class of nonlinear optimization problems where the optimal solution is also globally optimal.

1. Introduction:

Historical Development; Engineering applications of Optimization; Art of Modeling; Objective function; Constraints and Constraint surface; Formulation of design problems as mathematical programming problems; Classification of optimization problems based on the nature of constraints, the structure of the problem, deterministic nature of variables, separability of functions and the number of objective functions; Optimization techniques – classical and advanced techniques.

Lectures: 4

2. Linear Programming:

Standard form of linear programming (LP) problem; Canonical form of LP problem; Assumptions in LP Models; Graphical method for two variable optimization problem; Examples; Simplex algorithm with equality and inequality constraints, integer programming.

Lectures: 4

3. Optimization using Calculus:

Stationary points - maxima, minima, and saddle points; Functions of single and two variables; Global Optimum; Convexity and concavity of functions of one and two variables; Optimization of a function of single and multiple variables; Gradient vectors; Optimization of a function of multiple variables subject to equality; Lagrangian function; Hessian matrix formulation; Kuhn-Tucker Conditions.

Lectures: 8

4. Non-Linear Programming Algorithms:

Unconstrained optimization techniques, Direct search methods, Descent methods, 2nd order methods, constrained optimization, Direct and indirect methods.

Lectures: 6

5. Dynamic Programming:

Sequential optimization; Representation of multistage decision process; Concept of sub-optimization and the principle of optimality; Computational procedure in dynamic programming (DP); the curse of dimensionality in DP.

Lectures: 7

6. Robust Optimization Techniques:

Limitation of conventional optimization techniques, robust techniques: Simulated annealing (SA), Genetic Algorithm (GA)

Lectures: 7

Text Books:

1. S S Rao, Engineering Optimization: Theory and Practice, New Age International (P) Ltd.
2. Suresh Chandera, Jaydeva, Numerical Optimization with Applications, Narosa publisher.
3. David Edward Goldberg, Genetic Algorithms in Search, Optimization, and Machine Learning, Addison-Wesley Publishing Company.

Reference Books:

1. Edvin K P Chong, Stanislaw H Zak, An Introduction to Optimization, John Wiley.
2. Mohan C Joshi, Kannan M Moudgalya, Optimization Theory and Practice, Narosa

EEL XX13 POWER QUALITY

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- To study various methods of power quality monitoring.
- To Study, the production of voltages sags.
- To Study the interruptions types and their influence in various components.
- To Study the Effects of harmonics on various equipment.
- Understand power quality monitoring and classification techniques.

1. Introduction to Power Quality:

Terms and definitions: Overloading - under voltage - over voltage. Concepts of transients – short duration variations such as interruption - long duration variation such as sustained interruption. Sags and swells - voltage sag - voltage swell - voltage imbalance - voltage fluctuation - power frequency variations, different standers of power quality.

Lectures: 6

2. Voltage Sags and Interruptions:

Sources of sags and interruptions - estimating voltage sag performance. Thevenin's equivalent source - analysis and calculation of various faulted conditions. Voltage sag due to induction motor starting. Estimation of the sag severity - mitigation of voltage sags, active series compensators. Static transfer switches and fast transfer switches.

Lectures: 6

3. Overvoltages:

Sources of overvoltages - Capacitor switching – lightning - ferro resonance. Mitigation of voltage swells - surge arresters - low pass filters - power conditioners. Lightning protection – shielding – line arresters - protection of transformers and cables. An introduction to computer analysis tools for transients, PSCAD, and EMTP.

Lectures: 8

4. Harmonics:

Harmonic sources from commercial and industrial loads, locating harmonic sources. Power system response characteristics - Harmonics Vs transients. Effect of harmonics - harmonic distortion - voltage and current distortion - harmonic indices - inter harmonics – resonance. Harmonic distortion evaluation - devices for controlling harmonic distortion - passive and active filter design. IEEE and IEC standards.

Power Quality Improvement Scheme: STATCOM, UPQC

Power Quality EMI & EMC issues:

Lectures: 8

5. Power Quality Monitoring

Monitoring considerations - monitoring and diagnostic techniques for various power quality problems- modeling of power quality (harmonics and voltage sag) problems by mathematical simulation tools. Different power quality monitoring tools.

Lectures: 8

Text Books:

1. Roger. C. Dugan, Mark. F. McGranagham, Surya Santoso, H.WayneBeaty, 'Electrical Power Systems Quality' McGraw Hill, 2003.

2. C Sankaran, Power Quality, CRC press

Reference Books:

1. G.T. Heydt, Electric Power Quality, 2nd Edition. (West Lafayette, IN, Stars in a Circle Publications, 1994).

2. M.H.J Bollen, Understanding Power Quality Problems: Voltage Sags and Interruptions, (New York: IEEE Press, 1999).

3. J. Arrillaga, N.R. Watson, S. Chen, Power System Quality Assessment', (New York: Wiley, 1999.

EEL XX14 SCADA SYSTEM AND APPLICATIONS

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the basics of SCADA systems and their various functions.
- Acquire knowledge regarding SCADA System Components and Programmable Logic Controllers (PLC).
- Explore Various SCADA architectures, advantages, and disadvantages.
- Investigate various industrial communication technologies.
- Learn and apply the SCADA Applications in Transmission and Distribution sector operations and industries.

1. SCADA

Data acquisition system, evaluation of SCADA, communication technologies, monitoring, and supervisory functions. PLC: Block diagram, programming languages, Ladder diagram, Functional block diagram, Applications, Interfacing of PLC with SCADA.

Lectures: 10

2. SCADA System Components:

Schemes, Remote Terminal Unit, Intelligent Electronic Devices, Communication Network, SCADA server.

Lectures: 6

3. SCADA Architecture:

Various SCADA Architectures, advantages and disadvantages of each system, single unified standard architecture IEC 61850 SCADA / HMI Systems.

Lectures: 6

4. SCADA Communication:

Various industrial communication technologies- wired and wireless methods and fiber optics, open standard communication protocols.

Lectures: 8

5. SCADA Applications

Utility applications, transmission and distribution sector operation, monitoring analysis, and improvement. Industries, oil, gas, and water, Automatic substation control, SCADA requirement and configuration in energy control systems, Energy management system, system operating states, and system security.

Lectures: 6

Text Books

1. Stuart A Boyer, SCADA: Supervisory Control and Data Acquisition, ISA.
2. Gordan Clark, Deon Reynders, Practical Modem SCADA Protocols, Elsevier.

EEL XX15 SPECIAL ELECTRICAL MACHINES

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- To study stepper and Switched Reluctance Motors (Principle of operation, Types, Control techniques).
- To learn about Permanent Magnet Synchronous Motors and Brushless DC Motors (Principle of operation, Torque and voltage equations, Control techniques).
- To study about Servo and Linear Induction Motor (Principle of operation, Types, Control techniques)

1. Stepper Motors:

Constructional features, Principle of operation, Modes of excitation torque production in Variable Reluctance (VR) stepping motor, Dynamic characteristics, Drive systems and circuit for open loop control, closed-loop control of stepping motor.

Lectures: 4

2. Switched Reluctance Motors

Constructional features, Principle of operation. Torque equation, Characteristics, Control Techniques, Drive Concept.

Lectures: 6

3. Permanent Magnet Synchronous Motors and Brushless DC Motors

Principle of operation, EMF, power input and torque expressions, Phasor diagram, Power Controllers, Torque speed characteristics, Self-control, Vector control, and Current control Schemes. Commutation in DC motors, Difference between mechanical and electronic commutators, Hall sensors, Optical sensors, Multiphase Brushless motor, square wave permanent magnet brushless motor drives, Torque and emf equation, Torque-speed characteristics, Controllers-Microprocessors based controller.

Lectures: 8

4. Servomotors

Servomotor – Types – Constructional features – Principle of Operation – Characteristics - Control –Microprocessor-based applications.

Lectures:-6

5. Linear Motors

Linear Induction Motor (LIM) Classification – Construction – Principle of operation – Concept of Current sheet –Goodness factor – DC Linear Motor (DCLM) types – Circuit equation –DCLM control applications.

Lectures:6

6. Some Other Electrical Motor:

Reluctance and hysteresis motor, Universal Motor.

Lectures:6

Text Books:

1. Miller, T.J.E., Brushless Permanent Magnet and Reluctance Motor Drives, Clarendon Press, Oxford, 1989.
2. Kenjo, T, Stepping Motors and their Microprocessor control, Clarendon Press, Oxford, 1989.
3. K Venkataratam, Special Electrical Machines, University press.

Reference Books:

1. Naser A and Boldea I, Linear Electric Motors: Theory, Design, and Practical Application, Prentice Hall Inc., New Jersey,1987
2. Floyd E Saner, Servo Motor Applications, Pittman USA, 1993.

EEL XX16 MODERN CONTROL SYSTEMS

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Developing and analyzing state space models.
- Study the nonlinear system behavior by phase plane and describe function methods.
- Study the stability of linear and nonlinear systems by the Lyapunov method.
- Understand mathematical models of linear discrete-time control systems using transfer functions and state-space models.

1. State Variable Analysis and Design:

State space models, state space representation of simple electrical and mechanical systems, canonical forms, solution of state equation, state transition matrix, the relation between transfer function and state variable representations; controllability and observability, pole placement using state variable feedback; design of full order and reduced order observer, observer-based and state feedback controller, optimal control concept, solution of a linear quadratic regulator.

Lectures: 12

2. Sample Data Control System:

Mathematical preliminaries- difference equations, Z Transform and properties; sampling quantization and reconstruction process, discrete-time systems, system response, transfer function stability, bilinear transformation and the jury stability criterion, implementation of digital controllers and digital controllers for deadbeat performance. Root loci - Frequency domain analysis - Bode plots - Gain margin and phase margin - Design of Digital Control Systems based on Root Locus Technique, state space analysis of a discrete system.

Lectures: 12

3. Nonlinear Control Systems:

Characteristics of nonlinear systems; linearization techniques; phase plane analysis, singular points, limit cycle vs closed trajectory; stability analysis using phase plane analysis-describing function (DF) of common nonlinearities, stability analysis using DF; stability in the sense of Lyapunov, Lyapunov's stability theorems for linear and nonlinear systems; effect of non-linearity in root locus and Nyquist plot. Introduction to Modern Nonlinear control system. Introduction to a modern nonlinear control system.

Lectures: 12

Text Books

1. K. Ogata, Modern Control Engineering, Pearson Education, 2009
2. M. Gopal, Digital Control and State Variable Methods, Tata McGraw Hill, 2003
3. H.K.khalil, Non linear Systems, prentice, 3rd Edition.

Reference Books:

1. R. C. Dorf and R. H. Bishop, Modern Control Systems, Prentice Hall, 2010
2. B C. Kuo, Digital Control Systems, Oxford University Press, 1995 3. M. Gopal, Modern Control System Theory, New Age International, 1993

EEL XX17 SMART GRID PLANNING & OPERATION

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the analysis and planning of Smart Grids
- Evaluate the tools for modeling and analysis of smart grid dynamics,
- Analyze and synthesize different control schemes of smart grid operation
- Assess the influence of the smart grid on the power system

1. Analysis of Smart Grid System

Smart grid concepts, smart grid components, and control elements, Distributed generation resources and Energy Storage, Plug-in-Hybrid Electric Vehicles (PHEV), Smart Homes, Microgrids, Load Flow study for AC/DC smart grid analysis, Economic Dispatch, State Estimation for low voltage networks, smart grid Monitoring, smart grid standards, and policies.

Lectures: 4

2. Smart Grid Planning

Planning Aspects of smart grid, Operation and control of AC, DC, and hybrid smart grid, Optimal power flow, Demand side management of the smart grid, Demand response analysis of smart grid, Energy Management, Planning and Design of smart grid systems.

Lectures: 8

3. Voltage and Frequency Regulation of Smart Grid

Automatic generation Control, Load frequency control, Tie-line power sharing, Voltage Stability Assessment, Voltage stability Indexing, Concepts on the design of smart grid stabilizers to improve voltage stability, frequency & voltage regulations, and volt-VAR support.

Lectures: 12

4. Operation and Control of Smart Grids

Operational aspects of smart grid system, active and reactive power response, control objectives smart distribution system, architecture and different schemes of smart grid control, the bottleneck in smart grid control, and Ancillary Services. Advantages and disadvantages of different control schemes.

Lectures: 12

Text Books:

1. J. Momoh, "Smart Grid: Fundamentals of Design and Analysis," Wiley-IEEE Press, 1st Edition, 2012.
2. S. K. Salman, "Introduction to the Smart Grid: Concepts, Technologies and Evolution," IET Energy Engineering Series, 1st Edition,2017.

Reference Books:

1. Mini S Thomas and J. D MacDonald, "Power System SCADA and Smart Grid," CRC Press, 1st Edition,2015.
2. N. Hatziargyriou, "Microgrids Architecture and control", Wiley-IEEE Press Series, 1st Edition2013.

3. D. Mah, P. Hills, Victor O.K. Li, R. Balme, "Smart Grid Applications and Developments," Springer- Verlag London, 1st Edition,2014.
4. J. Ekanayake, N. Jenkins, K. Liyanage, J. Wu, A. Yokoyama, "Smart Grid: Technology and Applications," John Wiley & Sons, 1st Edition,2015.
5. G. Strbac, D. K. Rodrigo Moreno, "Reliability Standards for the Operation and Planning of Future Electricity Networks," IEEE, 1st Edition,2016.
6. Ali Keyhani, "Design of smart power grid renewable energy systems", Wiley IEEE, 2nd Edition2016.

EEL XX18 ADVANCED ELECTRIC DRIVES

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Study different types of Power Converters for DC and AC drives.
- Study different methods for Speed control of DC and AC drives.
- Study and analysis of special machine drives (PMSM, BLDC, SRM, Stepper motor)

1. Characteristics of Electric Motors:

Characteristics of DC motors, 3-Phase induction motors, and synchronous motors, Starting and braking of electric motors. Dynamics of Electric Drives, Mechanical system, Fundamental torque equations, components of load torques, Dynamic conditions of a drive system, Multi quadrant operation, Criteria for selection of motor for drives Energy loss in transient operations, Steady State Stability, Load equalization.

Lectures: 8

2. Converter Control of DC Drives

Analysis of series and separately excited DC motor with single-phase and three-phase controlled rectifiers operating in different modes and configurations. Analysis of series and separately excited DC motors fed from different choppers for both time ratio control and current limit control, four quadrant control. Single quadrant variable speed chopper fed DC drives. Four quadrants variable speed chopper fed DC Drives. Single phase/ three phases - dual converter fed DC Drive, design of speed, and current loop control. Different application.

Lectures: 10

3. AC Motor Drives:

Induction Motor Drive**:** Variable voltage variable frequency drive, Slip power recovery, Static Scherbius and Cramer drives. CSI fed Induction motor drives. Synchronous Motor Drive: variable frequency drives, self-control synchronous motor drives.

Lectures: 6

4. Special Motor Drives:

Brushless DC motor, Permanent magnet Synchronous motor, switched reluctance motor, stepper motor, linear induction, synchronous motor, and other advanced drives.

Lectures: 6

5. Advanced Control and Estimation of AC drives:

Small signal models, FOC control, sensorless control, DTC, model reference adaptive control, DSP, FPGA-based implementation control, and estimation technique.

Lectures: 6

Text Books:

1. M. H. Rashid, Power Electronics - Circuits, Devices and Applications, P.H.I Private Ltd. New Delhi.
2. B. K Bose, Modern Power Electronics and AC Drives, PHI
3. G.K. Dubey, Power Semiconductor controlled drives, Prentice Hall inc, A division of Simon and Schester England cliffs, New Jersey.
4. Sheperal, L.N. Wand Hully, Power Electronic, and Motor control, Cambridge University Press Cambridge
5. R Krishnan, Electric Drives-Modelling Analysis and control, PHI publication.

Reference Books:

1. S. Dewan, B. Slemon, A.G.R Straughen, Power Semiconductor drives, John Wiley and Sons, New York.
2. P.C. Sen, Thyristor DC Drives, John Wiley and Sons, NewYork.
3. V. Subramanyam, Electric Drives–Concepts and applications, TataMcGraw Hill Publishing Co., Ltd., New Delhi.
4. B.K. Bose, Power Electronics and Variable frequency drives, Standard Publishers Distributors

EEL XX19 TRANSACTIVE ENERGY MARKETS

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand Transactive Energy (TE)
- Understand Transactive Energy Resources
- Detail TE Techniques.
- Model TE and understand its application

1. Introduction to Transactive Energy (TE)

The potential impact of TE, Applications for Utilities and Distribution System Operators, and Customer Applications.

Lectures: 8

2. Renewable energy sources in a Transactive Energy market

Transactive Energy Products, Transactive Energy Market Participants, Transactive Energy Classification scheme for renewable market participants, Grid stability and protection, energy market management.

Lectures: 12

3. Transactive Energy Techniques

Conceptual View of Distributed Power Generation and Management Transactive Energy Construct, End- to-End Transactions of Information, Prices and Power, Centralized and Decentralized Transactive Energy.

Lectures: 8

4. Extension of Transactive Techniques from Wholesale to Retail

Price-based resource scheduling and dispatch, Congestion management, Transmission/distribution capacity auction, Market-clearing and pricing, and End-to-End Transactive Solutions Close the Gap between Wholesale and retail.

Mathematical Modeling and Economic Interpretation of Transactive Energy-based distribution system, case studies

Transactive Energy Application to Modern Grid and concept of blockchain techniques.

Lectures: 8

Text Books:

1. S. O. Muhanji, A.E. Flint, A. M. Farid, "eIoT: The Development of the Energy Internet of Things in Energy Infrastructure, Springer, 1st Edition,2019.
2. S. Barrager, E. Cazalet, "Transactive Energy: A Sustainable Business and Regulatory Model for Electricity", Baker Street Publishing, 1st Edition,2014.

References:

1. P. H. Divshali, B. J. Choi, H Liang, "Multi-agent transactive energy management system considering high levels of renewable energy source and electric vehicles", IET Generation, Transmission and Distribution, Vol. 11, No. 15, pp. 3713-3721,2017.
2. 'TransactiveControlandCoordinationofDistributedAssetsforAncillaryServices', U.S. Department of Energy, September 2013.
3. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22942.pdf
4. T. Sahin and D. Shereck, "Renewable energy sources in a transactive energy market," The 2014 2nd International Conference on Systems and Informatics (ICSAI 2014), Shanghai, pp. 202-208,2014.
5. Z. Liu, Q. Wu, S. Huang, and H. Zhao, "Transactive energy: A review of the state of the art and implementation," 2017 IEEE Manchester Power Tech, Manchester, pp. 1-6,2017.
6. P. H. Divshali, B. J. Choi and H. Liang, "Multi-agent transactive energy management system considering high levels of renewable energy source and electric vehicles," in IET Generation, Transmission & Distribution, vol. 11, no. 15, pp. 3713-3721,2017.
7. F. Lezama, J. Soares, P. Hernandez-Leal, M. Kaisers, T. Pinto, and Z. Vale, "Local Energy Markets: Paving the Path Toward Fully Transactive Energy Systems," in IEEE Transactions on Power Systems, vol. 34, no. 5, pp. 4081-4088, Sept.2019.
8. R. Ghorani, M. Fotuhi-Firuzabad, and M. Moeini-Aghtaie, "Main Challenges of Implementing Penalty Mechanisms in Transactive Electricity Markets," in IEEE Transactions on Power Systems, vol. 34, no. 5, pp. 3954-3956, Sept.2019.

LIST OF DEPARTMENTAL ELECTIVES: for SEMESTER- II

EEL XX21 SOFT COMPUTING TECHNIQUES AND APPLICATIONS

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Learn about soft computing techniques and their applications.
- Analyze various neural network architectures.
- Understand perceptions and counter-propagation networks.
- Define fuzzy systems.
- Analyze the genetic algorithms and their applications.

1. Introduction to Soft Computing:

Introduction, importance, main components, Fuzzy Logic, ANN, Evolutionary Algorithms, Hybrid Intelligent Systems.

Lectures: 4

2. Artificial Neural Network and Supervised Learning:

Introduction, Comparison of Neural Techniques and AI, Artificial Neuron Structure, Adaline, ANN Learning, Back Propagation Learning, Properties & Limitations.

Lectures: 5

3. Development of Generalized Neuron and Its Validation:

Existing Neuron Model, Development, Advantages, Learning Algorithm of a Summation Type Generalized Neuron, Benchmark Testing of Generalized Neuron Model, Generalization of GN model, Discussion.

Lectures: 5

4. Introduction to Fuzzy Set Theoretic Approach:

Introduction, Uncertainty and Information., Types of Uncertainty, Fuzzy Logic- Introduction, development, Precision and Significance, set, Operations, Union Intersection, Complement, Combination, Concentration, Dilation, Intensification, α-Cuts. Quantifier/Modifier/Hedges, Characteristics, Normality, Convexity, Cross Over Point, Singleton, Height, Cardinality, Properties of Fuzzy Sets, Fuzzy Cartesian Product, shape & defining Membership Functions, Defuzzification, Rule-Based System.

Lectures: 8

5. Applications of Fuzzy Rule-Based System:

Introduction, Modelling and Simulation, approach, selection, Steady State D.C. Machine Model, Control Applications Adaptive Control, PID Control System, Transient Model of D.C. Machine, Fuzzy Control System, Power System Stabilizer Using Fuzzy Logic.

Lectures: 4

6. Evolutionary & Metaheuristic search and optimization Algorithms:

GA-Selection, cross over & mutation, simple GA algorithm, elitism. PSO- Particle swarm, velocity, mutation, selection, algorithm. DE- Selection, cross over & mutation, algorithm, elitism.

Lectures: 6

7. Integration of Neural Networks, Evolution Algorithms, and Fuzzy Systems:

Adaptive Neuro-Fuzzy Inference Systems, Neuro-Fuzzy Approach of Modelling. ANN – GA-Fuzzy Synergism and Its Applications Training of ANN, ANN Learning Using GA, Validation and Verification of ANN-GA Model.

Lectures: 4

Prescribed Text Books

1. S N Sivanandam, S.N. Deepa, Principles of Soft Computing, Wiley.
2. Goldenberg, soft computing, Allied publisher.

Reference Books

1. D K Chaturvedi, Soft Computing - Techniques and its Applications in Electrical Engineering, Springer

EEL XX22 MODELING AND CONTROL OF POWER ELECTRONIC CONVERTERS

L-T-P: 3-0-0 **Credit: 3**

Course outcome

- To an analysis of the theoretical aspects of different converters and inverters.
- Understand the design aspects and components selection of a converter.
- Understand the Control aspects of the converters for simulation and implementation

1. Modelling of AC to DC converters:

Performance analysis of Line frequency single-phase and three-phase AC-DC converter under constant current load, Harmonic analysis of output voltage and input current under constant current load, selection of components for the design of single-phase and three-phase rectifiers, Design of filter circuit, Industrial Applications, Steady state converter analysis, Steady-state modeling of the power converters, Dynamic modeling of the AC to DC converters, AC modeling of converters, state-space averaging, Transfer functions and frequency domain analysis, Extra Element Theorem.

Lectures: 10

2. DC to DC Switch Mode Power Converters and their Control:

Introduction, steady state analysis of buck, boost, buck-boost, and cuk converter under a continuous and discontinuous mode of operation, steady state analysis of full-bridge DC-DC converter, components selection for the design of DC-DC converter and filters, Design of PWM techniques, Industrial Applications.

Lectures: 8

3. Design and Modelling of DC-AC Inverters:

Analysis of the performance of a single-phase switched mode inverter under PWM and square wave mode, their harmonic analysis. Performance analysis of a Three-phase inverter under PWM and square wave modes, their harmonic analysis, Selection of components for the design of single-phase and three-phase inverter components, Industrial Applications. Dynamic modeling of the DC to AC converters, AC modeling of converters, state-space averaging, Transfer functions and frequency domain analysis, Extra Element Theorem. Feedback control design, voltage mode, current mode control, control of inverters and rectifiers. Analog and digital implementation of the controllers, Advanced analysis, and control techniques applied to power electronics converters.

Lectures: 12

4. Design of Thermal and Magnetic Components:

Introduction, modes of heat transfer, a thermal model of power devices, Selection of heat sinks. Magnetic materials, hysteresis and eddy current losses in core, selection of parameters for the design of magnetic components for Power Electronic Applications, thermal consideration, design steps of an inductor.

Lectures: 6

Text Books

1. R. W. Erickson, D. Maksimovic, Fundamentals of Power Electronics, Kluwer Academic Publishers, 2004.
2. I. Batarseh, Power Electronic Circuits, Wiley, 2004.
3. J. Kassakian, M. F. Schlecht, and G. C. Verghese, Principles of Power Electronics, Addison-Wesley Publishing Company, 1991.

Additional Readings

1. S. B. Dewan &A. Straughen, Power Semiconductor Circuits, John Wiley & Sons, 1975
2. B.K Bose, Modern Power Electronics and AC Drives, Pearson Education, 2003

EEL XX23 DIGITAL CONTROL SYSTEMS

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Evaluate the output of a digital system for a given input.
- Describe the dynamics of Linear, Time-Invariant, and Causal digital systems through difference equations.
- Analyze digital systems using the Z-transformation.
- Design digital controllers for Power Electronic Systems

1. Introduction:

Digital control systems - Quantizing and quantization error - Data acquisition - Conversion and distribution system.

Lectures: 4

2. Z-Transform:

Z-transform - Z-transforms of elementary functions - Important properties and theorems - Inverse z- transform - Z-transform method of solving difference equations.

Lectures: 6

3. Z-Plane Analysis of Discrete-Time Control Systems:

Impulse sampling and data hold - Pulse transfer function - Realization of digital controllers and digital filters - Mapping between s-plane and z-plane - Stability analysis of closed-loop systems in z-plane - Transient and steady-state analyses.

Lectures: 8

4. State Space Analysis:

State space representation of digital control systems - Solution of discrete-time state space equations - Pulse transfer function matrix – Discretization of continuous time state space equations - Lyapunov stability analysis.

Lectures: 8

5. Pole Placement & Observer Design:

Controllability – Observability

Lectures: 5

6. Quadratic Optimal Control Systems:

Design via pole placement - State observer. - Quadratic optimal control - Steady state quadratic optimal control - Quadratic optimal control of a servo system.

Lectures: 5

Text Books:

1. M. Gopal, "Digital control engineering", New Age Int. Ltd., India, 2nd Edition, 2014.
2. K. Ogata, "Discrete-time control systems", Pearson Education, 2nd Edition, 2015.

Reference Books:

1. K. Ogata, "Modern control engineering" Pearson Education India, 5th Edition, 2015.
2. B. C. Kuo, "Digital control systems" Oxford University Press, 2nd Edition, 2012.

EEL XX24 MACHINE LEARNING AND DEEP LEARNING

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the basic concepts of Machine Learning and Deep Learning Techniques
- Distinguish between supervised learning and reinforced learning
- Develop the skill in using machine learning and deep learning software for solving practical problems
- Apply Machine learning and deep learning Algorithm to solve electrical Engineering Problems

1. Learning Theory

Introduction to Machine Learning: What is Learning- Learning Objectives-Data needed- Bayesian inference and Learning- Bayes theorem- inference- naïve Bayes- Regularization- Bias-Variance Decomposition and Trade-off- Concentration Inequalities-Generalization and Uniform convergence- VC- dimension- Types of Learning- Supervised Learning – Unsupervised Learning and Reinforcement Learning.

Lectures: 8

2. Supervised Learning

Simple linear Regression – Multiple Linear Regression- Logistic Regression – Exponential Family and Generalized Linear Models- Generative Models: Gaussian Discriminate Analysis Naïve Bayes- Kernal Method: Support Vector Machine (SVM)- Kernal function- Kernal SVM Gaussian Process- Tree Ensembles: Decision Trees- Random Forests- Boosting and Gradient Boosting.

Lectures: 10

3. Unsupervised Learning

K- mean Clustering Algorithm –Gaussian Mixture Model (GMM) –Expectation Maximization (EM)- Vibrational Auto Encoder (VAE)- Factor Analysis- Principal Components Analysis (PCA)- Independent component Analysis (ICA).

Lectures: 6

4. Reinforcement Learning

Markov Decision Processes (MDP)- Bellman's Equations-Value Iteration and Policy Iteration – Value Function Approximation-Q-Learning.

Lectures: 6

5. Deep Learning

Neutral Networks- Back progress Algorithm (BPM)- Deep Architectures- Convolution Neural Networks– Convolution Layer- Pooling Layer- Normalization Layer- Fully Connected Layer- Deep belief Networks- Recurrent Neural Networks. Use of machine learning and deep learning for forecasting generation and demand, predicting equipment and systems malfunctions and failures.

Lectures: 6

Text Books:

1. C. Bishop, "Pattern Recognition and Machine Learning", Springer, 2011.
2. E. Alpaydin, "Machine Learning", MIT Press, 2010

Reference Books:

1. Ian Goodfellow, Yoshua Bengio, and Aaron Courville, Deep Learning," MIT Press Cambridge, Massachusetts, London, England, 2016.
2. Tom, M. Mitchell, "Machine Learning", McGraw Hill International Edition, 1997.

EEL XX25 NUMERICAL OPTIMIZATION

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the concepts of convex sets, convex functions, and optimization problems, the concept of Duality, Lagrange dual problems, and optimality conditions.
- Study a few basic algorithms such as Descent methods, Newton's method, Conjugate direction methods, barrier method, and Primal-dual methods.
- Understand the mixed integer non-linear problem-solving methodologies and convex relaxation of non-linear non-convex problems.
- Learn the applications of optimization for power system problems such as unit commitment, economic load dispatch, optimal power flow, security-constrained optimal power flow, and state estimation problems.

1. Introduction to Convex sets, function, and optimization problems

Affine, convex sets, operations that preserve convexity, generalized inequalities, hyperplanes, basic convex function properties, conjugate functions, quasiconvex functions, and convexity concerning generalized inequalities. Linear optimization problems, quadratic optimization problems, geometric programming, and vector optimization.

Lectures: 6

2. Duality

TheLagrangedualfunction, Lagrange dual problem, Geometric interpretation, Saddle-point interpretation, Optimality conditions, Perturbation, and sensitivity analysis.

Lectures: 6

3. Algorithms

Unconstrained problems: Descent methods, Gradient descent method, Steepest descent method, Newton's method, Self-concordance, Conjugate direction methods.

Equality-constrained problems: Newton's method with equality constraints, infeasible start Newton method.

Inequality-constrained problems: Logarithmic barrier function and central path, barrier method, Feasibility, and phase I methods, Complexity analysis via self-concordance, Primal-dual methods.

Lectures: 8

4. Mixed Integer programming and Convex relaxations

Condensed formulation, Smooth and disjunctive reformulations: Disjunctive constraints, Big M method, smooth binary formulation, convex hull methods, Block-separable splitting-schemes: MINLP splitting- schemes, MIQQP splitting-schemes, Convexification of non-convex problems, SDP relaxation, SOCP relaxation, QCQP relaxation.

Lectures: 8

5. Power System Optimization

Unit commitment, Economic load dispatch, Optimal power flow, Security constrained optimal power flow, State estimation problems.

Lectures: 8

Text Books:

1. S. Boyd, L. Vandenberghe, "Convex Optimization", Cambridge university press, 1st Edition,2004.
2. David G. Luenberger, Yinyu Ye, "Linear and Nonlinear Programming", Springer Media, LLC, 3rd Edition,2008.

Reference Books:

1. Nowak, "Relaxation and Decomposition Methods for Mixed Integer Nonlinear Programming", Birkhäuser Verlag, 1st Edition,2005
2. J. Zhu, "Optimization of Power System Operation", Wiley IEEE Press, 2nd Edition,2015.

EEL XX26 DEREGULATED SMART GRIDS

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the need for restructured power system and economics.
- Discuss and analyze transmission congestion and loss allocation in Power System.
- Assess the role of demand response in smart grid systems.
- Evaluate economics and ancillary services within the Smart Grid.

1. Restructuring of the power industry and Fundamentals of Economics

Introduction, Reasons for restructuring/deregulation of the power industry, Fundamentals of Deregulation, Motivation of restructuring the power industries, restructuring process – unbundling & privatization, restructuring models and Trading Arrangements, Components of restructured systems.

Lectures: 4

2. Smart Grid in Power Market

Independent System Operator (ISO): Functions and responsibilities, Smart Grid trading arrangements (Pool, bilateral & multilateral), Open Access Transmission Systems, and Open Access Same Time Information system (OASIS). Definitions transfer capability issues: ATC, TTC, TRM, CBM calculations, methodologies to calculate ATC, Electricity Pricing.

Lectures: 6

3. Smart Grid Bidding Strategies

Forward and Future market; Operation and control: Old vs New, Integrated bidding strategy in the smart multi-energy system, Smart grid Optimization with risk constraints-General risk measures, Portfolio selection problem, penalty formulation.

Lectures: 6

4. Transmission Congestion Management

Classification of congestion management methods, Calculation of ATC-TTC-CBM, Non-market methods, Market-based methods, Nodal pricing, Inter-zonal Intra-zonal congestion management, and Price area congestion management.

Lectures: 4

5. Demand Response in Smart Grid

Demand response, Potential benefits of demand response in smart grid, enabling smart technologies for demand response, control devices for demand response, Monitoring, and communication system. Demand response for Electric Vehicles, Examples.

Lectures: 6

6. Ancillary Services within Smart Grid Framework

Reactive power as an ancillary service, Energy Storage System, Power Quality, Reliability analysis.

Lectures: 6

7. Smart Grid Economic and Market Operations

Energy and Reserve Markets, Market Power, Generation Firms, Locational Marginal Prices, and Financial Transmission Rights. Concepts of blockchain technologies in energy trading and power purchase agreements (PPA).

Lectures: 4

Text Books:

1. L. L. Lai, "Power System Restructuring and Deregulation", John Wiley & Sons Ltd., 1st Edition, 2012
2. D. Kirschen and G. Strbac, "Fundamentals of Power System economics", John Wiley & Sons Ltd, 2nd Edition 2019.

Reference Books:

1. S. Hunt, "Making competition work in electricity", John Wiley & Sons, Inc. 1st Edition, 2002.
   K. Bhattacharya, J. E. Daadler, and Math H.J Bollen, "Operation of restructured power systems", Kluwer Academic Pub. 1st Edition 2001 (Reprint 2012).

EEL XX27 MICROGRID DYNAMICS AND CONTROL

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the components of AC and DC microgrids
- Model and Analyze the behavior of Dynamic microgrids.
- Evaluate different hierarchical control schemes and communication between them.
- Analyze the influence of microgrids on electrical markets.

1. Concept of Microgrids

Introduction to the concept of microgrid, the overview of the structure and architecture of microgrid with brief control, operational aspects. Recent pilot microgrid projects and their outcomes.

Lectures: 4

2. Decentralized Local Controllers

AC-microgrids: Control Mechanism of the DGs connected in the microgrid. Virtual synchronous generator (VSG) and Droop control. Transient frequency response, active power Response, reactive power sharing, and voltage regulation.

DC-microgrids: DC microgrid control mechanism, droop control, issues in achieving active power sharing with impedance droop, remedies to achieve active power sharing.

Lectures: 6

3. Power System Stability

Power system stability classification, Basic definitions of transient, dynamic, and small signal stability Generator and load modeling, modeling and analysis of SMIB systems.

Lectures: 4

4. Dynamic and Stability Analysis of Microgrids

Dynamic modeling of individual components in AC and DC microgrids, state space modal analysis and influence of system parameters on the microgrid dynamics, brief concept on the design of microgrid stabilizers to improve stability.

Lectures: 6

5. Hierarchical Control Scheme for Microgrids

Control Objectives in AC Microgrids, bottleneck with only local control, need for secondary and tertiary control, implementation of hierarchical control with centralized and distributed control schemes for AC and DC microgrids. Advantages and disadvantages of centralized and distributed control schemes.

Lectures: 4

6. Multi-microgrid Coordination and Control

AC-AC, AC-DC, and DC-DC micro gird clustering, coordinated control schemes in multi-microgrids, frequency, voltage regulations, and volt-VAR support.

Lectures: 4

7. Control of Smart Power Grid System

Load Frequency Control (LFC) in Micro Grid System – Voltage Control in Micro Grid System – Reactive Power Control in Smart Grid. Case Studies and Testbeds for the Smart Grids.

Lectures: 4

8. Techno-Economic Analysis of Microgrids

Technical, economic, and environmental benefits of microgrids, Quantification of microgrids benefits under standard test conditions, market pricing, and policies.

Lectures: 4

Text Books:

1. N. D. Hatziargyriou, "Microgrids Architecture and control", IEEE Press Series, John Wiley & Sons Inc, 1st Edition,2013.
2. H. Bevrani, B. François, T. Ise, "Microgrid Dynamics and Control", John Wiley & Sons, 1st Edition, 2017.

Reference Books:

1. A. Bidram, V. Nasirian, A. Davoudi, F. L. Lewis, "Cooperative Synchronization in Distributed Microgrid Control", Springer, 1st Edition,2017.
2. P. Kundur, "Power System Stability and Control", McGraw-Hill, Inc., 2nd Edition,1994.

EEL XX28 ADVANCED POWER ELECTRONICS AND DRIVES

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- To review basic concepts of power electronics in the field of power control and drives
- To address the underlying concepts and methods behind Advanced Power Electronics
- knowledge of power semiconductor technologies and their advancement in the field of power conversion.

1. Introduction:

review of power semiconductor devices: Thyristor, IGBT, MOSFET, IGCT, GTO and their driver circuits, role of SiC in power semiconductor technology.

Lectures: 6

2. AC-DC converter:

Uncontrolled rectifier, semi-controlled rectifiers, fully controlled rectifiers with R, RL and RLE load, effect of source inductance on performance of converter, firing schemes and circuits, MULTIPULSE CONVERTERS: Multi-pulse converters: 12,18 and 24 pulse converters, phase shifting transformers POWER FACTOR: power factor improvement techniques, PWM rectifiers: equal area PWM, sine PWM, Single Phase and Three phase boost rectifier circuits.

Lectures: 6

3. DC-AC converters:

Voltage Source Inverter: 120º and 180º conduction modes, PWM techniques of voltage fed converters: Selective Harmonic Elimination (SHE), sine modulation, Third harmonic injection, Hysteresis Current Control, Sigma-Delta Modulation, Space Vector Pulse Width Modulation: undermodulation and overmodulation and their implementation Current Source Inverter: Current Source inverters and their role in high power drives: Autosequential Current Fed inverter, Pulse Width Modulation of CSI Matrix converters: Three phase matrix converters and their control, basic input filter, protection of matrix converter.

Lectures: 10

4. Multilevel inverters:

Diode Clamped MLI, Flying Capacitor MLI, Cascaded H-Bridge topology: operation with equal and unequal DC voltages, Carrier modulation schemes of multilevel inverter, SVPWM of Multilevel inverter, Neutral Point Balancing schemes.

Lectures: 8

5. Advance Electrical Drives:

Brushless DC motor: Sinusoidal and Trapezoidal BLDC motor, Electronic Commutator, Torque production in BLDC motor, Control of Brushless DC drives Switched Reluctance Motor: Elementary Operation and Principle of operation, Modes of operation, Converter circuits for SRM: Asymmetric Bridge Converter, R-Dump, Bifilar Type converter

Lectures: 6

Readings:

Prescribed Text Books

1. Ned Mohan, T.M. Undeland and William P.Robbins, Power Electronics: Converters, Applications, 3rd Edition, John Wiley & Sons, 2009.
2. M. H. Rashid, Power Electronics-Circuits, Devices and Applications, 3rd Edition, PHI, 2005
3. C.W Lander, Power Electronics, McGraw-Hill book company, 1981

Additional Readings

1. M. D. Singh & K. B. Khanchandani, Power Electronics, McGraw Hill.
2. Undeland and Robins, Power Electronics – Concepts, applications, and Design Mohan,
3. L. Umanand, Power Electronics, Essentials, and Applications
4. Fundamental of Power Electronics, Robert W.erickson, Academic publishers

EEL XX29 GRID INTEGRATION OF ELECTRIC VEHICLES

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the Electric Vehicle concepts and their importance in power systems.
- Assess the role of EVs in modern distribution systems and smart grids
- Understand the technology, design methodologies, and control strategy of hybrid electric vehicles.
- Understand the operation and importance of EVs in Grid Applications, grid balancing, ancillary services and demand response

1. Fundamentals of Electric Vehicles (EV)

Introduction to Electric Vehicle technology – Types –Fundamental issues related to electric vehicles (EVs) and hybrid electric vehicles (HEVs) – Interdisciplinary Nature of EVs – State of the Art of EVs – Advantages and Disadvantages – Challenges and Key Technologies of EVs – Challenges for EV Industry in India.

Lectures: 6

2. Electric Vehicle Batteries

Electric vehicle battery efficiency – type – capacity –charging/discharging –technical characteristics – performance – testing, EV battery for stationary applications (B2U).

Lectures: 8

3. Charging Techniques

Architecture/Components of EV charging station –EVSE (Electric Vehicle Supply Equipment) – Type of EV Chargers – Charging Methods – Automotive networking and communication, EV and EV charging standards.

Lectures: 10

4. Grid Applications

Concept of Vehicle to Grid (V2G/G2V)–Ancillary Services – peak saving – load-generation balance – Demand Response – Energy time shift – Energy Management strategies and its general architecture – integration of EVs in smart grid, social dimensions of EVs.

Lectures: 6

5. Advanced Topics

Different design and control aspects of electric drives and chargers for EVs and HEVs, Battery Charger Topologies, and Infrastructure for Plug-In-Electric and Hybrid Vehicles –Impact of Plug-in Hybrid Electric Vehicles on smart Grid/Distribution Networks – Sizing Ultracapacitors for Hybrid Electric Vehicles, the concept of a vehicle to Home (V2H), Effect of charging infrastructure on grid protection and control.

Lectures: 6

Text Books:

1. James Larminie, John Lowry, "Electric Vehicle Technology Explained", Wiley-Blackwell, 2nd Edition,2012.
2. Sheldon S. Williamson, "Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles", Springer, 1st Edition,2016

References:

1. Sandeep Dhameja, "Electric Vehicle Battery Systems," Elsevier, 1st Edition,2012.
2. Ali Emadi, "Advanced Electric Drive Vehicles," CRC Press, 1st Edition,2017.
3. Iqbal Hussain, "Electric & Hybrid Vehicles Design Fundamentals", 2nd Edition, CRC Press,2011.
4. Chris Mi, M. Abul Masrur, D. Wenzhong Gao, A Dearborn, "Hybrid electric Vehicles Principles and applications with practical perspectives," John Wiley & Sons Ltd., 2nd Edition,2017.
5. T. Muneer and I. Illescas García, "The automobile, In Electric Vehicles: Prospects and Challenges", Elsevier, 1st Edition,2017.
6. S. Rajakaruna, F. Shahnia, and A. Ghosh, "Plug-In Electric Vehicles in Smart Grids", Springer Singapore, 1st Edition,2015.
7. J. Lu, and J. Hossain, "Vehicle-to-Grid: Linking electric vehicles to the smart grid", IET, 1st Edition, 2015

N. B. Arias, S. Hashemi, P. B. Andersen, C. Træholt, and R. Romero, "Distribution System Services Provided by Electric Vehicles: Recent Status, Challenges, and Future Prospects", IEEE Transactions on Intelligent Transportation Systems, 2019, (early access)

EEL XX30 CLOUD COMPUTING AND BIG DATA ANALYTICS IN SMART GRIDS

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Enumerate research integrating cloud computing and big data applications for smart grid
- Analyze the benefits of cloud computing and big data analytics for smart grid technology.
- Explore applications of big data and cloud computing.
- Evaluate the current status of smart grid simulation tools

1. Introduction:

Introduction to Cloud Computing in Smart Grid - Introduction to Big Data Analytics - Fundamental Mathematical Prerequisites, Big Data Era, General Security Challenges.

Lectures: 6

2. Cloud Computing Applications for Smart Grid:

Cloud computing in smart grid, Cloud computing architecture, Demand Response - Geographical Load- Balancing - Dynamic Pricing - Virtual Power Plant - Advanced Metering Infrastructure - Cloud-Based Security and Privacy.

Lectures: 7

3. Smart Grid Data Management and Applications:

Pricing and energy forecasting in Demand Response, case study on Energy Forecast, Smart Meter Data Management -PHEVs: Internet of Vehicles - Smart Buildings.

Lectures: 7

4. Smart Grid Design and Deployment:

Attack detection, current problem, and techniques, Secure Data Learning Scheme, Logical Security Architecture, Smart Metering Data Set Analysis—A Case Study, Security Schemes for AMI Private Networks, Simulation Tools- Worldwide Initiatives.

Lectures: 8

5. Probability and Statistics:

Random variable and sample space, empirical approach to probability - conditional probability - independent events - Bayes' Theorem, mathematical expectation - moment generating function - Chebyshev's inequality - Bernoulli trials - the Binomial, negative binomial, geometric, Poisson, normal, rectangular, exponential, Gaussian, beta and gamma distributions, sampling and large sample tests, chi-square test, theory of estimation, linear and polynomial fitting by the methods, correlation of bivariate frequency distribution.

Lectures: 8

Text Books:

1. S. Misra and S. Bera, "Smart Grid Technology A Cloud Computing and Data Management Approach" Cambridge University Press, 1st Edition,2018.
2. F. Ye, Y. Qian and R.Q. Hu, "Smart Grid Communication Infrastructure: Big Data, Cloud Computing, and Security" Wiley IEEE Press, 1st Edition,2018.

Reference Book:

1. James A. Momoh, "Smart Grid: Fundamentals of Design and Analysis" Wiley India, 1st Edition, 2015

EEL XX31 CHALLENGES AND SOLUTIONS IN RENEWABLE INTEGRATION

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the available grid Codes for renewable integration in multiple countries.
- Understand market and forecasting challenges due to uncertainties in renewables.
- Assess power quality and inertia issues with increased penetration of RES in electric grids.
- Evaluate solutions and apply them for RES operational and uncertainty issues.

1. **Energy System Challenges:**

Handling Renewable Energy Variability and Uncertainty in Power System Operation, short-term frequency response challenges in power systems with high nonsynchronous penetration levels, technical impacts of high penetration levels of wind power on power system stability, constraints to the transformation rate of global energy infrastructure, demand-supply flexibility, Voltage control, inertia response. Overview of the grid codes, components of the grid codes, development of the grid codes, classification and specifications of the grid codes, anomalies in grid codes, Fault-Ride Through criterion.

Lectures: 6

2. Integration of Renewable Energy:

The Indian Experience Policy initiatives, Regulatory initiatives, Transmission planning initiatives, Experience with RECs in India, Challenges German Renewable Energy Sources Pathway: Increasing challenges of RES integration into the German electricity system. Danish Case Study: The Danish markets for balancing the electricity system, making wind a part of the balancing solution, an hour with negative prices for downward regulation, Challenges to participation in the tertiary reserve market, and Decentralized combined heat and power plants of the balancing solution. Texas Case Study: Study of the impacts of wind generation on ancillary service, Ancillary service requirement methodology improvements to integrate wind generation resources, Regulation-up and - down reserve service.

Lectures: 8

3. Photovoltaic Penetration in Distribution Network:

Voltage imbalance sensitivity analysis, stochastic evaluation, Monte Carlo Evaluation, series and parallel custom power devices, dynamic and feasibility issues related to custom power, the performance of the grid-connected solar photovoltaic system with MPPT controllers, a mathematical model of grid-connected three-phase SPV system, performance evaluation of P&O and INC based MPPT algorithms, application of adaptive neuro-fuzzy inference system (ANFIS) for control of DC-DC convertor for SPV system.

Lectures: 6

4. Market Operations and Forecasting Renewables:

Analyzing the impact of variable energy resources on power system reserves, Advances in Market Management Solutions for Variable Energy Resources Integration, forecasting Renewable Energy for Grid Operations, Incorporating Forecast Uncertainty in Utility Control Centers, Reserve Management for Integrating Renewable Generation in Electricity Markets, Scandinavian Experience of Integrating Wind Generation in Electricity Market, Economics of renewable generation integration and long term power purchase agreements (PPA) Solution for RES Uncertainties. Enabling and disruptive technologies for renewable integration, enhancing situation awareness in power systems: overcoming uncertainty and variability with renewable resources, managing operational uncertainty through improved visualization tools in control centers concerning renewable energy providers, Synchro phasors for distribution networks with variable resources, Monitoring and control of RES using synchronized phasor measurements.

Lectures: 10

5. Solution for Operational Issues:

Virtual inertial, reactive power control in response to voltage deviations, use of energy storage systems, advanced control strategies to improve dynamic and transient response time, and Derated operation of renewable resources.

Lectures: 6

Text Books:

1. J. Hossain and A. Mahmood, Renewable energy integration: Challenges and Solutions, Springer- Verlag, 2014 Edition,2014.
2. L. E. Jones, “Renewable Energy Integration Practical Management of Variability, Uncertainty, and Flexibility in Power Grids”, Elsevier Inc., 2nd Edition,2017.

References Books:

1. L. Bird, M. Milligan, and D. Lew, “Integrating Variable Renewable Energy: Challenges and Solutions”, Technical Report NREL/TP-6A20-60451 September 2013.
2. AkshayUrja, “Challenges to Grid Integration of Renewable Energy in India”, MNRE technical report,2019.
3. F. Katiraei and J. R. Aguero, “Solar PV Integration Challenges,” IEEE Power and Energy Magazine, vol. 9, no. 3, pp. 62-71, May-June2011.
4. L. Xie et al., “Wind Integration in Power Systems: Operational Challenges and Possible Solutions,” in Proceedings of the IEEE, vol. 99, no. 1, pp. 214-232, Jan.2011.

EEL XX32 SMART ELECTRICAL DISTRIBUTION SYSTEM

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the structure and load patterns of a power distribution system.
- Model and analyze modern smart power distribution systems.
- Analyze the performance of distribution power flow and short circuit studies.
- Suggest/follow Regulations and Market Models for a Smart distribution system.

1. Introduction

Fundaments of the Electrical Power Distribution System and feeder configuration, Distribution system loading, Load Characteristics, SAIDI, SAIFI, Distribution Transformer, Single phase, and three Phase Transformer connections.

Lectures: 6

2. Distribution System Modeling

The impedance of the distribution system, Modeling of distribution line, cables, Distribution Transformer, Distributed generation, loads, and reactive power sources. Modeling and study of voltage regulators in a distribution network.

Lectures: 6

3. Distribution System Analysis

Load flow for distribution system: Backward/forward method, Direct method, load flow application for the weakly meshed distribution system, Short Circuit analysis: Sequence-based, Thevenin Equivalent and Phase variable based, LG, LL, LLG, LLLG fault analysis and its applications.

Lectures: 6

4. Smart Distribution Technologies

Distribution automation, outage management systems, automated meter reading (AMR), automated metering infrastructure (AMI), Net Metering, Automated Fault Location, Isolation, and Service Restoration, Outage Management Systems (OMS), Energy Storage, Renewable Integration, Microgrids. Impacts of microgrids, EV charging, and rooftop solar in the smart electric distribution system.

Lectures: 8

5. Regulations and Market Models for Smart Distribution System

Demand Response, Tariff Design, Time of the day pricing (TOD), Time of use pricing (TOU), Consumer privacy and data protection, consumer engagement, etc. Cost-benefit analysis of smart grid projects.

Lectures: 10

Text Books:

1. A.S. Pabla, "Electric Power Distribution", Tata McGraw Hill Publishing Co. Ltd., 4th Edition, 2017.
2. Abdelhay A. Sallam and Om P. Malik, "Electric Distribution Systems," IEEE Press Series, 2nd Edition,2019.

Reference Books:

1. W. H. Kersting, "Distribution System Modeling and Analysis", CRC Press, 4th Edition, 2017.
2. John D. McDonald (Editor), "Electric Power Substations Engineering", CRC Press, 3rd Edition, 2016.

EEL XX33: HIGH VOLTAGES AND INSULATION ENGINEERING
L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Elucidate the concepts used for the generation and measurement of high voltages and currents and design corresponding circuits.
- Understand breakdown phenomena in gases and elucidate the concepts used for the generation of high voltages and currents.
- Understand high voltage testing techniques of Power apparatus and causes of overvoltage in Power systems.
- Understand the generation of transients and the concept of insulation coordination.

1. Overview of High Voltage Engineering and Electrostatic Field distribution:

Overview of High Voltage Engineering and numerical methods applied in calculating electrostatic field in complex insulating configurations.

Lectures: 2

2. Generation of high voltages and currents, AC voltages:

Cascade transformers-series resonance circuits DC voltages: voltage doubler-cascade circuits-electrostatic machines Impulse voltages: single stage and multistage circuits wave shaping-tripping and control of impulse generators Generation of switching surge voltage and impulse currents.

Lectures: 8

3. Measurement of high voltages and currents:

DC, AC and impulse voltages and currents-DSO-electrostatic and peak voltmeters-sphere gaps-factors affecting measurements-potential dividers (capacitive and resistive)-series impedance ammeters-rogowskicoils-hall effect generators.

Lectures: 6

4. Breakdown mechanisms in Solid, Liquid, and Gaseous Dielectrics:

Solid Dielectrics Breakdown through Intrinsic, Thermal, Electrochemical, Treeing, Tracking, partial discharges, Liquid Dielectrics Breakdown through Electronic, in Pure and Commercial Dielectric, Breakdown in uniform and non-uniform fields-Paschens law-Townsends criterion-streamer mechanism-corona discharge-breakdown in electronegative gases.

Lectures: 8

5. Lightning and Switching Transients, Insulation Coordination:

Transients and their causes and Effects, Use of Bewley Lattice Diagram in the calculation of Transients, Nominal and Maximum System Voltage, Factor of Earthing, Insulation Level, Earth Wire, Conventional and Statistical methods of Insulation Coordination.

Lectures: 6

6. High voltage testing of materials and apparatus:

Preventive and diagnostic tests-dielectric loss measurements-Schering bridge-inductively coupled ratio arm bridge-partial discharge and radio interference measurement-testing of circuit breakers and surge diverter.

Lectures: 6

Text Books:

1. Kuffel, Zaengl, Kuffel, High Voltage Engineering Fundamentals, Newnes Publications, 2000.
2. C.L. Wadhwa , High Voltage Engineering, New Age publication, 2007

EEL XX34 ANALYSIS OF POWER CONVERTERS

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Appropriate Selection of switching devices and energy Transactive/ handling components for power converters realizations.
- Analyze and design power converter configurations for specific applications
- Suggest efficient control techniques for low and medium-power converters
- Design and Evaluate power electronic converters for improved power quality

1. Overview of Switching Power Devices

Static and dynamic characteristics of switching devices: BJT, MOSFET, IGBT, GTO, Wide band gap devices (GaN, SiC) - Design of driver and snubber circuit.

Lectures: 8

2. DC-DC Converters

Non-isolated DC-DC converters: buck, boost, buck-boost, CUK converters under continuous and discontinuous conduction operation - Isolated DC-DC converters: forward, fly-back, push-pull, half-bridge and full-bridge converters - Relationship between I/P and O/P voltages - design of filter inductor and capacitors.

Lectures: 10

3. Inverters

Single-phase and three-phase inverters - PWM techniques: single, multiple, and sinusoidal PWM techniques - selective harmonic elimination, space vector modulation, current source inverter- High power inverters: multi-pulse inverters, multi-level inverters - Diode-clamped, cascaded and Flying capacitor types, Carrier and Vector based multi-level modulation schemes -Concept of active power filters- Introduction to MatrixConverters.

Lectures: 12

4. Front-End (AC-DC) Converters

Conventional methods of power factor improvements: Semi-converter, extinction angle control, symmetrical angle control – active front-end converters - Single phase: Boost, voltage doubler and PWM rectifiers –voltage and current controlled three-phase PWM rectifiers.

Lectures: 6

Text Books:

1. M. H. Rashid, "Power Electronics Handbook", Butterworth-Heinemann, 4th Edition,2017.
2. N. Mohan, T.M. Undeland, W.P. Robbins, "Power Electronics: Converters, Applications", John Wiley & Sons, 3rd Edition,2003.

Reference Books:

1. L. Umanand, "Power Electronics: Essentials and Applications", John Wiley India, 1st Edition,2009.
2. J. Baliga B, "Fundamentals of Power Semiconductor Devices", Springer, 1st Edition2008.
3. Bin Wu, "High Power Converters and AC Drives", Wiley-Inter Science, 2nd Edition,2017.
4. D. A Paice, "Power Electronic Converter Harmonics Multipulse Method for Clean Power", IEEE Press,1995

EEL XX35 DATA SCIENCE APPLICATIONS IN POWER ENGINEERING

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Distinguish between Algorithmic based methods and Knowledge-based Methods
- Able to distinguish between Artificial Neural Networks and Fuzzy Logic
- Adopt Soft Computing techniques for solving Power Systems and Power Electronics and Drives Problems
- Apply appropriate AI framework for solving power systems and Power Electronics & Drives Problems

1. Artificial Neural Networks (ANN):

Introduction to Artificial Neural Networks - Definition and Fundamental concepts -Biological Neural Network – Modeling of a Neuron -Activation functions – initialization of weights -Typical architectures-Leaning/Training laws - Supervised learning Unsupervised learning – Reinforcement learning-Perceptron – architectures-Linear Separability – XOR Problem -ADALINE and MADALINE.

Lectures: 9

2. ANN Paradigms:

Multi–layer perceptron using Backpropagation Algorithm (BPA)-Self-Organizing Map (SOM)- Learning Vector Quantization (LVQ) - Radial Basis Function Network -Functional link network -Hopfield Network -Bidirectional Associate Memory (BAM).

Lectures: 9

3. Fuzzy Logic:

Introduction – Classical and Fuzzy sets- Properties, Operations, and relations-Fuzzy sets – Membership function – Basic Fuzzy set operations -Properties of Fuzzy sets – Fuzzy Cartesian Product - Operations on Fuzzy relations – Fuzzy logic – Fuzzy Cardinalities -Fuzzy Logic Controller (FLC): Fuzzy Logic System Components: Fuzzification- Inference Engine -Defuzzification methods.

Lectures: 10

4. Applications of ANN & Fuzzy Logic:

Load flow studies -Economic load dispatch -Load frequency control – Single area system and two area systems -Reactive power control -Speed control of DC and AC Motors.- PWM Vector controlled drive -Speed estimation and flux estimation of induction motor.

Lectures: 8

Text Books:

1. S. Rajasekaran and G. A. V. Pai, "Neural Networks, Fuzzy Systems, and Evolutionary Algorithms: Synthesis and Applications", PHI, New Delhi, 2nd Edition, 2017.
2. T. J. Ross, "Fuzzy Logic with Engineering Applications", Mc Graw Hill Inc, 3rd Edition, 2011.

Reference Books:

1. Simon Haykin: Neural Networks: A Comprehensive Foundations, Pearson Edition, 2003
2. G.J. Klir and T.A. Folger: Fuzzy sets, Uncertainty and Information, PHI, Pvt. Ltd, 1994.
3. Bart Kosko: Neural Network & Fuzzy System, Prentice Hall, 1992.
4. P.D. Wasserman: Neural Computing Theory & Practice, Van Nostrand Reinhold Co. New York, 1st Edition, 1989.

EEL XX36 SIGNAL PROCESSING IN SMART GRIDS

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the applications of Digital signal filtering techniques in power systems
- Apply estimation techniques to evaluate power system parameters
- Understand different signal decomposition techniques
- Understand the WAMS signal processing

1. Power Systems signals in terms of Smart Grid

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.

Lectures: 6

2. Power Systems and signal processing

Stochastic gradient-based algorithms – LMS algorithm, Normalized LMS algorithm, Gradient adaptive lattice algorithm. Mean-squared error behavior, 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.

Lectures: 9

3. Filters and Electrical Parameters Estimation

Forward and backward linear prediction, prediction error filters, AR lattice and ARMA Lattice – Ladder filters, Kalman filters, Wiener filters, and Least Square methods for system modeling & 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.

Lectures: 9

4. 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.

Lectures: 6

5. Signal Processing Techniques Applications

Concepts of wavelet, s-transform, Heartly's-transforms; Hilbert transform; Gabor transform, and applications in power fluctuations: load fluctuations, wind farm power fluctuations, and smart microgrid.

Lectures: 6

Text Books:

1. J.G.Proakis, M. Salehi, "Advanced Digital Signal Processing", McGraw –Hill, 1992.
2. P. F. Ribeiro, C. A. Duque, P. Marcio da Silveira and A. S. Cerqueira, "Power Systems Signal Processing for Smart Grids," John Wiley and Sons Ltd., 2nd Edition, 2014.

Reference Books:

1. S. Haykin, "Adaptive Filter Theory", Prentice Hall, 2nd Edition, 2001.
2. J. V. Candy, Signal Processing, The Model-Based Approach, McGraw-Hill Book Company, 1987
3. M. H. Hayes, "Statistical Digital Signal Processing and modeling", John Wiley & Sons, 1996
4. Handouts on DSP Processors.
5. S. K. Mitra, Digital Signal Processing – A Computer Based Approach, MGH, 2nd Edition, 2001.

EEL XX37 ADAPTIVE AND ROBUST CONTROL SYSTEMS

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the fundamental concepts of adaptive and Robust control system
- Design the adaptive controllers for the Micro Grid system
- Suggest robust control and design robust droop controller using loop shaping methods
- Design and apply a nonlinear robust controller with a suitable and efficient control approach for Micro Grids.

1. Introduction

Overview of Adaptive Control-Adaptive Schemes-Formulation of Adaptive Control problem-Preliminaries: Lyapunov Stability-Parameter Estimation: Least squares and Regression models- Recursive least squares (RLS)- Estimating parameters in Dynamic systems-Convergence of Parameter Estimation algorithms- Prediction error (PE) model structures-One step ahead PE method.

Lectures: 6

2. Self-Tuning Regulator (STR)/ Model Reference Adaptive Systems (MRAS)

Certainty Equivalent Principle-Pole placement design- direct self-tuning regulators -Indirect self-tuning regulators, continuous time self-tuners, Hybrid self-tuners- disturbances with known characteristics- The MIT rule- Determination of Adaptation gain- Design of MRAS using Lyapunov theory- Relationship between MRAS and STR.

Lectures: 8

3. Auto Tuning and Gain Scheduling

Auto tuning Principle and Techniques, Transient response methods- Methods based on Relay feedback- Relay Oscillation- Gain scheduling: the principle - Design of Gain scheduling controllers- Case Study: Adaptive droop control of Microgrid.

Lectures: 7

4. Robust Control

Types of Uncertainty -Kharitonov Theorem: Applications to Robust PI/PID controller design-Robust Stability /Performance Condition- H_2 and H_∞ norms-Concept of Loop Shaping-Controller design using the loop shaping methods: H_∞ Control, Quantitative feedback theory (QFT)- Case Study: Loop shaping methods to Robust droop control of Microgrid.

Lectures: 8

5. Sliding Mode Control (SMC)

Motivation-Matched and Unmatched Uncertainty-Sliding surface design- Stability of SMC-Equivalent control concept- Integral Sliding Mode Control (ISMC)- Composite nonlinear feedback (CNF) controller- Application of SMC to Load frequency control in Microgrid.

Lectures: 7

Text Books:

1. K.J. Astrom, B. Wittenmark, "Adaptive Control", Addison-Wesley, 2nd Edition,1995.
2. I. Postlethwaite, S.Skogestad, "Multivariable Feedback Control: Design and Analysis", Wiley Publisher, 2nd Edition,2014.

Reference Books:

1. P.A. Ioannou, J. Sun, "Robust Adaptive Control", Dover Publications, 2nd Edition,2013.
2. C. Edwards, S.K. Spurgeon, "Sliding Mode Control: Theory and Applications", Taylor and Francis Publisher, 1st Edition,1998
3. I.D. Landau, R. Lozano, and M. M'Saad, A. Karimi, "Adaptive Control: Algorithms, Analysis and Applications", Springer, 2nd Edition,2011.

EEL XX38 EVOLUTIONARY ALGORITHMS APPLICATION IN POWER ENGINEERING

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Discriminate the capabilities of the bio-inspired system and conventional methods in solving Optimization problems.
- Examine the importance of exploration and exploitation of swarm intelligent systems to attain near-global optimal solutions.
- Distinguish the functioning of various swarm intelligent systems.
- Employ various bio-inspired algorithms for Power systems engineering applications.

1. Fundamentals of Soft Computing Techniques

Definition-Classification of optimization problems- Unconstrained and Constrained optimization Optimality conditions- Introduction to intelligent systems- Soft computing techniques- Conventional Computing versus Swarm Computing - Classification of meta-heuristic techniques - Single solution-based and population-based algorithms – Exploitation and exploration in population-based algorithms - Properties of Swarm intelligent Systems - Application domain - Discrete and continuous problems - Single objective and multi-objective problems.

Lectures: 8

2. Genetic Algorithm and Particle Swarm Optimization

Genetic algorithms- Genetic Algorithm versus Conventional Optimization Techniques - Genetic representations and selection mechanisms; Genetic operators- different types of crossover and mutation operators -Bird flocking and Fish Schooling – anatomy of a particle-equations based on velocity and positions -PSO topologies - control parameters – GA and PSO algorithms for solving ELD problem.

Lectures: 8

3. Artificial Bee Colony Algorithms and Differential evolution

Artificial Bee Colony (ABC) Algorithm Binary ABC Algorithm- ACO and ABC algorithms for solving Economic dispatch of thermal Units, Motivation for differential Evolution (DE), Introduction to parameter optimization, single point, derivative-based optimization, Local vs Global optimization, Differential mutation, Recombination, Selection, Benchmarking differential evolution, DE vs other Optimizers, DE and parallel processors.

Lectures: 8

4. Shuffled Frog-Leaping Algorithm and Bat Optimization Algorithm

Bat Algorithm- Echolocation of bats- Behaviour of microbats- Acoustics of Echolocation-Movement of Virtual Bats- Loudness and Pulse Emission- Shuffled frog algorithm-virtual population of frog's comparison of memes and genes -memeplex formation- memeplex updation- BA and SFLA algorithms for solving ELD and optimal placement and sizing of the DG problem.

Lectures: 6

5. Multi-Objective Optimization

Multi-Objective optimization Introduction- Concept of Pareto optimality - Non-dominant sorting technique-Pareto fronts-best compromise solution-min-max method-NSGA-II algorithm and applications to power systems.

Lectures: 4

6. Advanced Techniques

Soft sensor concepts in power systems.

Lectures: 2

Text Books:

1. Xin-She Yang, "Recent Advances in Swarm Intelligence and Evolutionary Computation," Springer International Publishing, Switzerland,2015.
2. Kalyanmoy Deb, "Multi-Objective Optimization using Evolutionary Algorithms," John Wiley & Sons,2001.
3. James Kennedy and Russel E Eberheart, "Swarm Intelligence," The Morgan Kaufmann Series in Evolutionary Computation,2001.

Reference Books:

1. Eric Bonabeau, Marco Dorigo and Guy Theraulaz, "Swarm Intelligence-From natural to Artificial Systems," Oxford University Press,1999.
2. David Goldberg, "Genetic Algorithms in Search, Optimization and Machine Learning," Pearson Education,2007.
3. Konstantinos E. Parsopoulos and Michael N. Vrahatis, "Particle Swarm Optimization and Intelligence: Advances and Applications," Information science reference, IGI Global,2010.

EEL XX39 SMART APPLIANCES AND INTERNET OF THINGS

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand and evaluate the characteristics of smart home appliances.
- Understand the behavior of IoT and its applications.
- Manage smart communication systems with multiple sensors and protocols.
- Design and simulate smart homes and smart cities with IoTs and cloud computing

1. Modern Domestic Appliances

Solid State Lamps: Introduction - Review of Light sources - white light generation techniques-Characterization of LEDs for illumination application. Power LEDs- High brightness LEDs-Electrical and optical properties. LED driver considerations-Power management topologies - color issues of white LEDs- Dimming of LED sources, BLDC motors for pumping and domestic fan appliances, inverter technology-based home appliances, Smart devices and equipment.

Lectures: 8

2. IoT Communication Technologies

Introduction to IoT, Sensing, Actuation, Basics of Networking, Communication Protocols, Sensor Networks, and Machine-to-Machine Communications. Interoperability in IoT.

Lectures: 9

3. IoT Control Technologies and Programming

Introduction to Arduino Programming, Integration of Sensors and Actuators with Arduino, Internet of Things Open-Source Systems Introduction to Python programming, Introduction to Raspberry. Implementation of IoT with Raspberry Pi, Smart Grid Hardware Security.

Lectures: 10

4. IoT Cloud Computation and Applications

Introduction to SDN. SDN for IoT, Data Handling and Analytics, Cloud Computing, Sensor-Cloud. Fog Computing, Smart Cities and Smart Homes, Electric Vehicles, Industrial IoT, Case Study: Agriculture, Healthcare, Activity Monitoring.

Lectures: 9

Text Books:

1. Vinod Kumar Khanna, "Fundamentals of Solid-State Lighting", CRC press, 1st Edition,2014.
2. Chang-Liang Xia, "Permanent Magnet Brushless DC Motor Drives and Controls", John Wiley & Sons Singapore Pte. Ltd, 1st Edition,2012.
3. K. Siozios, D. Anagnostos, D. Soudris, E. Kosmatopoulos, "IoT for Smart Grids Design Challenges and Paradigms", Springer, 1st Edition,2019.

References Books:

1. Craig Di Louie, "Advanced Lighting Controls: Energy Saving Productivity, Technology & Applications", Fairmont Press, Inc., 1st Edition,2006.
2. Robert S Simpson, "Lighting Control: Technology and Applications", Focal Press, 1st Edition,2003.
3. Arturas Zukauskus, Michael S. Shur& Remis Gaska, "Introduction to solid state lighting", Wiley- Interscience, 1st Edition,2002.

EEL XX40 SMART GRID RESILIENCY AND CYBERSECURITY

L-T-P: 3-0-0 **Credit: 3**

Course Outcomes:

- Understand the key technical threat types, communication protocols, and resilient smart grid architectures.
- Deploy risk management, operational security, and secure development of Smart Grid.
- Assess static and dynamic security analysis techniques to validate.
- Verify smart grid security and resiliency

1. Smart Grid Security Challenges

Security Goals and Challenges, Importance of security, Classification of the threats, Security Analytics for AMI and SCADA, Security Analytics for EMS Modules, Overview of SMT, and Probabilistic Model Checking. **Lectures : 8**

2. Security and Data Privacy in Smart Grid

Security Challenges in Smart Grid Implementation, Legal Protection of Personal Data in Smart Grid and Smart Metering Systems, Phases of smart grid system development cycle, Smart Grid Security and Privacy of Customer-Side Networks, Smart Grid Security Protection against False

Data Injection (FDI) Attacks, Smart Grid Security, Secure V2G Connections, End-to-End security with devices/equipment, sensors, controllers, actuators, communication, and systems.

Lectures: 10

3. Smart Grid Threat and Cross-Domain Risk

Smart Grid threat Landscape, Smart Grid Risk Assessment, Challenges and solutions, Emerging methods, and techniques for smart grid security.

Lectures: 10

4. Smart Grid Resiliency and Cyberattack

Types of physical attack on smart grid devices, Hardware security modules, Analytics for Smart Grid Security and Resiliency, Cyber security solutions for control and monitoring systems, Control centric security tools and risk assessment methodology, Secure Communications in Smart Grid: Networking and Protocols.

Lectures: 8

Text Books:

1. Al-Shaer, Ehab, Rahman and Mohammad Ashiqur, "Security and Resiliency Analytics for Smart Grids', Springer Intr., 1st Edition,2016.
2. S. Goel, Goel, Y. Hong, V. Papakonstantinou, D. Kloza, "Smart Grid Security", Springer-Verlag, 1st Edition,2015

Reference Books:

1. A. Abdallah and X. Shen, "Security and Privacy in Smart Grid", Springer Intr., 1st Edition,2018.
2. Abdul Rahamanet al., 'Smart grids security challenges: Classification by sources of threat', Journal of Electrical Systems and Information Technology, 5 (3), pp. 468-483,2018.
3. A. Abur and A. G. Exposito, "Power System State Estimation: Theory and Implementation", CRC Press, 1st Edition,2004.
4. Roy D. Yates, David J. Goodman, "Probability and Stochastic Processes: A Friendly Introduction for Electrical and Computer Engineers", Wiley, 3rd Edition,2014.