VEERMATA JIJABAI TECHNOLOGICAL INSTITUTE
**(VJTI)**
MATUNGA, MUMBAI 400 019

(Autonomous Institute affiliated to University of Mumbai)

Curriculum
(Scheme of Instruction & Evaluation and Course contents)

For
Two Year Postgraduate Programme Leading to
Master of Technology (M.Tech.) Degree in
Electrical Engineering with specialization in Power Systems



**Implemented from the batch admitted in Academic Year 2014-15**

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In

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## SEMESTER I

| Scheme of Instruction | | | | Scheme of Evaluation | | | | |
|---|---|---|---|---|---|---|---|---|
| **S. No** | **Course code** | **Course Title** | **L-T-P (Hours / week)** | **Credits** | **TA** | **IST** | **ESE** | **ESE hours** |
| 1. | EE5001S | Computational Methods | 3-1-0=4 | 4 | 20 | 20 | 60 | 3 |
| 2. | EE5051S | Power System Protection and Relaying (PSPR) | 3-1-0=4 | 4 | 20 | 20 | 60 | 3 |
| 3. | EE5052T | Advanced Power Systems (APS) | 3-0-0=3 | 3 | 20 | 20 | 60 | 3 |
| | EE5052P | Advanced Power System Lab | 0-0-2=2 | 1 | 100 % CIE | | | |
| 4. | EE5053T | Linear Control Design (LCD) | 3-0-0=3 | 3 | 20 | 20 | 60 | 3 |
| | EE5053P | Linear Control Design Lab | 0-0-2=2 | 1 | 100 % CIE | | | |
| 5. | | Program Elective Course 1 | 3-1-0=4 | 4 | 20 | 20 | 60 | 3 |
| | | Program Elective Course 2 | 3-0-0=3 | 3 | 20 | 20 | 60 | 3 |
| 6. | | Program Elective Course 2 Lab | 0-0-2=2 | 1 | 100 % CIE | | | |
| | | **Total** | **27** | **24** | | | | |

## SEMESTER II

| Scheme of Instruction | | | | Scheme of Evaluation | | | | |
|---|---|---|---|---|---|---|---|---|
| **S. No** | **Course code** | **Course Title** | **L-T-P (Hours / week)** | **Credits** | **TA** | **IST** | **ESE** | **ESE hours** |
| 1. | EE5005S | Research Methodology | 3-1-0=4 | 4 | 20 | 20 | 60 | 3 |
| 2. | EE5054S | Restructured Power System (RPS) | 3-1-0=4 | 4 | 20 | 20 | 60 | 3 |
| 3. | EE5055T | Power System Stability (PSS) | 3-0-0=3 | 3 | 20 | 20 | 60 | 3 |
| | EE5055P | PSS Lab | 0-0-2=2 | 1 | 100 % CIE | | | |
| 4. | EE5008T (Common PS+CS) | System Identification, Estimation and Filtering (SIEF) | 3-0-0=3 | 3 | 20 | 20 | 60 | 3 |
| | EE5008P | SIEF Lab | 0-0-2=2 | 1 | 100 % CIE | | | |
| 5. | | Program Elective Course 3 | 3-0-0=3 | 3 | 20 | 20 | 60 | 3 |
| 6. | | Program Elective Course 4 | 3-0-0=3 | 3 | 20 | 20 | 60 | 3 |
| | | Program Elective Course 4 Lab | 0-0-2=2 | 1 | 100 % CIE | | | |
| | EE5801D | Technical Seminar* | 0-0-4=4 | 2 | 100 % CIE | | | |
| | | **Total** | **30** | **25** | | | | |

Abbreviations: **L**: Lecture, **T**: Tutorial, **P**: Practical, **TA**: Teacher Assessment / Term work Assessment, **IST**: In Semester Tests (comprise of average of two In semester tests), **ESE**: End Semester Written Examination, **CIE**: Continuous In-semester Evaluation

## List of Electives:

| Sr. No | Course code | Course Title |
|---|---|---|
| **Program Elective Course 1** | **EE5151S** | Smart Grid and Development |
| | **EE5152S** | Power Quality |
| | **EE5153S** | Power Electronics and FACTS devices |
| **Program Elective Course 2** | **EE5154T** | Renewable Energy Systems |
| | **EE5155T** | High Voltage Engineering |
| | **EE5156T** | Digital Signal Processing |
| **Program Elective Course 3** | **EE5161S** | High Performance Electric Drives |
| | **EE5162S** | Power Plant Component Design |
| | **EE5163S** | High Voltage Transmission Systems |
| **Program Elective Course 4** | **EE5164T** | Insulation System Design |
| | **EE5165T** | Cyber Security for Smart Grid |
| | **EE5166T** | Substation Automation |

**SEMESTER III and SEMESTER IV – Project work**

| S. No | Course Category | Course Code | Course Title | Credits | Evaluation pattern | Semester |
|---|---|---|---|---|---|---|
| 1. | Project | EE6901D | Stage –I Presentation | 4 | Graded evaluation by a committee of atleast two examiners including supervisor (guide) | III |
| 2. | Project | EE6902D | Stage –II Presentation | 4 | Graded evaluation by a committee of atleast two examiners including supervisor (guide) | III |
| 3 | Project | EE6903D | Stage –III Presentation | 4 | Graded evaluation by a committee of at least two examiners including guide (guide) | IV |
| 4. | Project | EE6904D | Final Presentation and Viva Voce | 12 | Graded evaluation by a committee of atleast two examiners including supervisor (guide) and an external examiner | IV |

## PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

*The Post Graduate students shall be able to*

- *Address challenges of the future innovations in Electrical Engineering & Technology.*
- *Play an effective role in the multidisciplinary research*
- *Develop leadership and team building skills.*

## PROGRAM OUTCOMES (POs)

*The Post Graduate students after completion of course shall;*

- *Strong fundamentals in Electrical Engineering.*
- *Better analytical and mental capabilities, particularly to grasp large power system networks.*
- *Conversant with practical power system design, operation, control, and testing issues.*
- *Correlate simulation results using professional software with mathematical analysis & practical systems.*
- *Communicate effectively and convey the ideas acquired through research.*
- *An understanding of professional and ethical responsibilities.*

| | |
|---|---|
| **Programme Name** | **M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER I** |
| **Course Code** | **EE5001S** |
| **Course Title** | **COMPUTATIONAL METHODS** |

## COURSE OBJECTIVES

- Students will be able to develop mathematical models of lower level engineering problems.
- Students will learn how to solve nonlinear equations numerically.
- Students will be introduced to fundamental matrix algebra concepts and shown how to solve simultaneous linear equations numerically.
- Students will learn how to curve fit (interpolation and regression) discrete date.
- Students will learn how to numerically integrate continuous and discrete functions.
- Students will learn how to numerically solve ordinary differential equations that are initial value or boundary value problems.

## COURSE OUTCOMES

- Understand the concept and steps of problem solving - mathematical modeling, solution and implementation.
- Knowledge and understanding of, and the ability to use, mathematical techniques.
- Ability to understand and apply mathematical reasoning in several different areas of mathematics.

### Overview

| **Module 1: Algebraic Equations** | |
|---|---|
| | Formulation and solution of linear system of equations, Gauss elimination, LU, QR decomposition, iteration methods (Gauss-Seidal), convergence of iteration methods, Singular value decomposition and the sensitivity of rank to small perturbation |
| **Module 2: Interpolation & Regression Methods** | |
| | Newton's divided difference, interpolation polynomials, Lagrange interpolation polynomials, Linear and non-linear regression, multiple linear regression, general linear least squares |
| **Module 3: Transform Techniques** | |
| | Vector spaces, Basis vectors, Orthogonal/Unitary transform, Fourier transform, Laplace transform |
| **Module 4: Optimization Techniques for Engineers** | |
| | Local and global minima, Line searches, Steepest descent method, Conjugate gradient method, Quasi Newton method, Penalty function |
| **Module 5: Graph Theory** | |
| | Graphs and Matrices, simple graph, cyclic graph, complete graph, properties of the Laplacian matrix and relation with graph connectivity. Non-negative matrices. Applications of graph theory to engineering problems. |

## Recommended Reading


1. "Numerical Methods for Engineers', Steven C. Chapra and Raymond P. Canale, McGraw Hill
2. "Probability and Statistics in Engineering and Management Studies", Hines and Montrogmery, John Willey
3. "Numerical Methods for Engineers", Santosh Gupta, New age international publishers
4. "Graphs and Matrices", R. B. Bapat, TRIM Series, Hindustan Book Agency, 2011
5. "Algebraic Graph Theory ", C. Godsil and G. Royle, Springer, New York, (Available in Indian edition)

| | |
|---|---|
| **Programme Name** | **M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER I** |
| **Course Code** | **EE5051S** |
| **Course Title** | **POWER SYSTEM PROTECTION AND RELAYING** |

**COURSE OBJECTIVES**

- To provide extensive knowledge of power system protection measurements, control and relay logic.
- To impart knowledge of designing schemes of protection, relay coordination and numerical relays.
- To provide basic knowledge of various aspects of power system protection both theoretical and practically as implemented in industry.

**COURSE OUTCOMES**

- Students shall be able to design protection scheme including proper relay co-ordination for a given power system.
- Students shall be able to work on different practical projects on both conventional and numerical protection.
- Students shall be able design special protection scheme to enhance system stability.

## Overview

| |
|---|
| **Module 1: Introduction** |
| Power system Protection, Prevention and control of system failure, Protective system design consideration, Definitions used in System Protection, System disturbances. |
| **Module 2: Protection Measurements and Controls** |
| Graphic symbols and device connections, Typical relay connections, Circuit Breaker Control Circuits, Instrument Transformers-Selection, Types and Connections, Relay control configurations, Optical Communications. |
| **Module 3: Protective Device Characteristics** |
| Relay characteristics, Power circuit breakers, Automatic circuit reclosure and line sectionalizes, Circuit switches and digital fault recorders. |
| **Module 4: Relay Logic** |
| Analog relay logic, Digital relay logic, Hybrid relay logic, Relays as comparators |
| **Module 5: System Characteristics** |
| Computation of available fault current, System equivalent for protection studies, Compensation theorem, Compensation application in fault studies. |
| **Module 6: Protection against Abnormal frequency** |
| Abnormal frequency operation, Effects of frequency on generator, Frequency effects on the turbine, system frequency response module, Off normal frequency protection, under frequency protection. |
| **Module 7: Protective schemes for stability enhancement** |
| Review of stability fundamentals, System transient behavior, Automatic reclosing, Loss of synchronism protection, Special protection schemes. |
| **Module 8: Digital Protection Of Power Systems** |

| |
|---|
| Introduction to computer relaying: Development and historical background, expected relay architecture, A-D converters, Anti –aliasing Filters, substation computer hierarchy |
| Review of mathematical basis for protective relaying algorithms: Fourier series, Orthogonal expansions, Fourier transforms, Discrete Fourier transforms, Introduction to probability and random processes, Kalman Filtering. |

## Recommended Reading


1. Anderson PM, “Power system protection,” McGraw-hill, 1999``
2. Singh LP, “Digital protection
3. Badri Ram & Vishwakarma, “Power system protection and SWG,” McGraw Hill
4. Mason CR, “The art and science of protective relaying,” John Wiley & sons
5. J. Lewis Blackburn & T. J. Domin, “Protective Relaying Principles & Applications”
6. Computer relaying for Power systems, Arun G Phadke and James S Thorp, John Wiley & Sons Inc, New York.

| Programme Name | M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER I |
|---|---|
| Course Code | EE5052T |
| Course Title | ADVANCED POWER SYSTEM (APS) |

**COURSE OBJECTIVES**

- To provide extensive knowledge of power system protection measurements, control and relay logic.
- To impart knowledge of designing schemes of protection, relay coordination and numerical relays.
- To provide basic knowledge of various aspects of power system protection both theoretical and practically as implemented in industry.

**COURSE OUTCOMES**

- Students shall be able to design protection scheme including proper relay co-ordination for a given power system
- Students shall be able to work on different practical projects on both conventional and numerical protection
- Students shall be able design special protection scheme to enhance system stability.

**Overview**

| |
|---|
| **Module 1: Revision of load flow** |
| **Module 2: An introduction to state estimation in power systems:** |
| Introduction, least square estimation method, weighted Least square estimation, gross errors and their effects observability |
| **Module 3: Power system security** |
| Introduction, factors affecting power system security, contingency analysis: Z bus and Y bus contingency, concepts of Z bus building algorithm, detection of network problems, correcting the generation approach. |
| **Module 4: Economic dispatch of thermal units** |
| The economic dispatch problems, thermal system dispatching with network losses considered, the lambda-iteration method, first order gradient method, base point and participation factors |
| **Module 5:Synchronous machine theory and modeling** |
| Physical description, mathematical description of a synchronous machine, the dq0 transformation, per unit representation, equivalent circuit for direct and quadrature axis, steady state analysis, electrical transient performance characteristics, equations of motion. |
| **Module 6:Excitation systems** |
| Excitation system requirements, elements of excitation systems, types of excitation systems, dynamic performance measures, control and protective functions, modeling of excitation systems |
| **Module 7:Prime movers and energy supply systems** |
| Hydraulic turbines and governing systems, Steam turbines and governing systems. |

**Recommended Reading**

1. Power generation operation and control: Wood and Woolenberg
2. Power System dynamics and Stability : Prabha Kundur

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|---|---|
| **Programme Name** | **M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER I** |
| **Course Code** | **EE5052P** |
| **Course Title** | **ADVANCED POWER SYSTEM LAB** |

**COURSE OBJECTIVES**

- To provide extensive knowledge of power system protection measurements, control and relay logic.
- To impart knowledge of designing schemes of protection, relay coordination and numerical relays.
- To provide basic knowledge of various aspects of power system protection both theoretical and practically as implemented in industry.

**COURSE OUTCOMES**

- Students shall be able to design & simulate power system network.
- Students shall be able to perform load flow, contingency analysis etc. in simulation environment.

**Overview**

1. Load flow analysis
2. Voltage control by tap changing transformer
3. Voltage control using excitation control
4. Reactive power control
5. Contingency analysis
6. Basic optimal power flow
7. Optimal power flow with losses and various constraints

| Programme Name | M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER I |
|---|---|
| **Course Code** | **EE5053T** |
| **Course Title** | **LINEAR CONTROL DESIGN** |

**COURSE OBJECTIVES**

- Control system analysis: analysis of properties of control systems, such as sensitivity, stability, controllability, tracking, in time and frequency domains;
- Control system design: design of feedback controllers to meet desired system performance specifications
- Introduction to modern robust control theory techniques for large- scale uncertain systems: stability and performance; computer-aided tools for both system analysis and controller design

**COURSE OUTCOMES**

- The student shall be able to appreciate and apply the acquired knowledge of mathematics and science to real world problems across different disciplines of engineering
- The students shall be able to ability to identify, formulate, and solve control related engineering problems.
- The students shall be able to specify, design, analyze and test a wide range of systems to meet a set of desired goals, within the context of a broader system application.

**Overview**

| **Module 1** |
|---|
| Introduction to basic control theory, Issues in control system design, Design via root locus, Design via Frequency response, Design via state-space. |
| **Module 2** |
| Basic review of Stability theory, Root locus methods, Bode methods, Nyquist theory. |
| **Module 3** |
| Dynamic compensation in time domain and frequency domain |
| **Module4** |
| State space modelling, Controllability and observability concepts, Observer's and Controller design |
| **Module 5** |
| Introduction to concepts of model uncertainty, including both parametric and dynamic uncertainty. Fundamental concept of robustness and the relationship between physical systems and mathematical models. Mathematical background including norms for vectors, matrices, signals, and systems. The singular value decomposition (SVD) and its application to perturbation analysis |
| **Module6** |
| Loop shaping, the basic technique of loop shaping, The phase formula, optimal controllers, Plants with RHP poles and zero's. |

**Recommended Reading**


1. John Doyle, Bruce Francis, Allen Tannenbaum, "Feedback Control Systems", Macmillan Publishing Co.1990.

2. Kemin Zhou, “Robust And Optimal Control”, Prentice Hall, Englewood Cliffs, New Jersey. Norman S. Nise, “Control Systems Engineering”, John Wiley & Sons.
3. Joao P. Hespanha, “Linear Systems Theory”, Princeton University Press.

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|---|---|
| **Programme Name** | **M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER I** |
| **Course Code** | **EE5053P** |
| **Course Title** | **LINEAR CONTROL DESIGN LAB** |

**COURSE OBJECTIVES**

- Control system analysis: analysis of properties of control systems, such as sensitivity, stability, controllability, tracking, in time and frequency domains;
- Control system design: design of feedback controllers to meet desired system performance specifications
- Introduction to modern robust control theory techniques for large- scale uncertain systems: stability and performance; computer-aided tools for both system analysis and controller design.

**COURSE OUTCOMES**

- The student shall be able to apply the acquired knowledge of mathematics in-order to apply control for any given application.
- The students shall design and perform simulation of various compensator circuits.

**Overview**

1. To plot bode plot, Nyquist plot and root locus of the given system
2. To study controllability and observability of the given systems
3. To design lead compensator using SISO tools
4. To study compensation using pole placement method.
5. To design a simple pendulum using Simulink

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|---|---|
| **Programme Name** | **M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER I** |
| **Course Code** | **EE5151S** |
| **Course Title** | ***PROGRAM ELECTIVE COURSE 1***<br>**SMART GRID DESIGN AND DEVELOPMENT** |

**COURSE OBJECTIVES**

- To provide students with a comprehensive understanding on design and analysis of smart grids
- To ensure that the students are aware of the current state-of-the-art on design, operation and control of smart grid
- To enable students to apply advanced analysis tools in planning and operation of smart grids.

**COURSE OUTCOMES**

- Upon completion of the subject, students will be able to understand the fundamental elements and structure of the smart power grid
- Upon completion of the subject, students will be able to apply this knowledge in analysis and problem solving of smart grid architectures needs and challenge
- Upon completion of the subject, students will be able to be introduced to communication, networking, and sensing technologies involved with the smart grid

**Overview**

| |
|---|
| **Module 1: Introduction** |
| Evolution of Electric Grid, concept of Smart Grid, definitions, need of Smart Grid, functions of Smart Grid, opportunities and barriers of Smart Grid, difference between conventional and Smart Grid, concept of resilient and self-healing Grid, ase studies of Smart Grid, CDM opportunities in Smart Grid. |
| **Module 2: Smart Grid Technologies** |
| Introduction to Smart Meters, real time prizing, Smart appliances, Outage Management System (OMS), Plug in Hybrid Electric Vehicle (PHEV), Vehicle to Grid, Smart sensors, Home and building automation, Smart substations, substation automation, feeder automation, Geographic Information Systems (GIS), Intelligent Electronic Devices (IED) & their application in monitoring & protection, Smart storage like Battery, SMES, Pumped Hydro Compressed Air Energy Storage, Super capacitors |
| **Module 3: Micro grids and Distributed Energy Resources** |
| Concepts of micro grid, need and applications of micro grid, formation of micro grid, issues of interconnection, protection and control of micro grid, renewable energy, energy storage; solar energy, wind energy, biomass, hydropower, geothermal and fuel cell; effect of electric vehicles (EVs), captive power plant, integration of renewable energy sources. |
| **Module 4: Power Quality in Smart Grid** |
| Power quality & EMC in Smart Grid, power quality issues of grid connected renewable energy sources, power quality conditioners for Smart Grid, |
| **Module 5:Information & Communication Technology for Smart Grid** |
| Advanced Metering Infrastructure (AMI), Home Area Network (HAN), Neighborhood Area |

| |
|---|
| Network (NAN), Wide Area Network (WAN), Bluetooth, ZigBee, GPS, Wi-Fi, Wi-Max based communication, Wireless mesh network. Wide Area Measurement System (WAMS), Phase measurement unit (PMU), cyber security for Smart Grid, IP based protocols, reliability, redundancy |
| **Module 6: Smart grid implementation** |
| Policy and economic drives of the smart grid; environmental implications; sustainability issues; state of smart grid implementation |

**Recommended Reading**


1. JanakaEkanayakae, KithisiriLiyanage, Jianzhong Wu, Akhiko Yokoyama, and Nick Jenkins, “Smart Grid: Technology and Applications”, A John Wiley and sons, Ltd, 2012
2. James Momoh, “Smart Grid: Fundamentals of Design and Analysis”, IEEE Press, John Wiley and sons, Ltd, 2012.
3. Chetan Singh Solanki, Solar Photovoltaics: Fundamentals, Technologies and Applications, PHI publication, Second edition
4. Joshua Earnest and Tore Wizelius, Wind Power Plants and Project Development, PHI publication
5. Solar Energy International , Photovoltaics: Design and Installation Manual, New Society Publishers
6. Brendan Fox, Wind Power Integration: Connection and System Operational Aspects, The Institution Of Engineering And Technology

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|---|---|
| **Programme Name** | **M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER I** |
| **Course Code** | **EE5152S** |
| **Course Title** | ***PROGRAM ELECTIVE COURSE 1***<br>**POWER QUALITY** |

**COURSE OBJECTIVES**

- To introduce to students the term and definition of power quality disturbances, and their causes, detrimental effects and solutions.
- To introduce the harmonic sources, passive filters, active filters and standards.
- To prepare students to know the power quality monitoring method, equipments and develop the ability to analyse the measured data.

**COURSE OUTCOMES**

- Ability to explain power quality disturbances and typical problems associated with power quality disturbances.
- Ability to solve problems on harmonic distortion on electrical power systems.
- Ability to design basic filters to reduce harmonic distortion.
- Ability to explain the typical equipment that either causes or is susceptible to electrical power quality disturbances.

**Overview**

| |
|---|
| **Module 1: Introduction** |
| Power Quality Introduction, Indices of Quality of supply, Voltage magnitude variations, System frequency errors, Operating imbalances, Quantifying waveform distortions |
| **Module 2: Waveform Distortion** |
| Harmonic distortion, sources of harmonics, adverse consequences of harmonics, Harmonic measurements, Transducers for harmonic measurements, locating harmonic sources by measurements |
| **Module 3: Harmonic Analysis** |
| Harmonic analysis methods, Parametric techniques, Statistical approach to harmonic analysis, Network models for harmonic analysis, Harmonic resonances, Harmonic filtering, Optimal harmonic filter design |
| **Module 4: Corona** |
| Corona noise, Conductor surface states and weather conditions, Evaluation of noise levels, Noise data recordings, Signal-to-noise ratio and the quality of reception, Television interference, Noise measurement Principles, Radio-noise meters, Bandwidth, ANSI and CISPR standards, Frequency Spectrum of noise, Discharge pulse Wave shape, |
| **Module 5:** |
| The excitation function in Power Spectral-density form, Radiated Noise fields, Lateral Profiles and frequency spectra, Computer-based evaluation Procedures, Principal Design Options, Radiated Noise Fields, Comparison of Noise Field levels for different Design Options, Evaluation of Active Power loss due to Corona, Nonlinear Voltage charge Characteristics, Dependences of Corona loss on Weather conditions, Conductor surface conditions and surface gradient, separation into Reduced loss and Reduction factor, Typical loss evaluation. |

**Recommended Reading**

1. M. H. J. Bollen, "Understanding Power Quality Problems, Voltage Sag & Interruptions", New York: IEEE Press, 2000, Series On Power Engineering
2. R. C. Dugan, Mark F. McGranghan, Surya Santoso, H. Wayne Beaty, "Electrical Power System Quality", 2nd Edition, McGraw Hill Pub
3. J. Arrillaga, M. R. Watson, S. Chan, "Power System Quality Assessment", John Wiley and Sons

| Programme Name | M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER I |
|---|---|
| **Course Code** | **EE5153S** |
| **Course Title** | ***PROGRAM ELECTIVE COURSE 1***<br>**POWER ELECTRONICS & FACTs DEVICES** |

**COURSE OBJECTIVES**

- To understand the basic operation of power electronic devices.
- To acquire the knowledge on flexible AC Transmission System and its importance for FACTS controllers.
- To understand the various FACTS controllers operation on FACTS systems.

**COURSE OUTCOMES**

- To apply knowledge of FACTS Controllers and design a Compensators within realistic constraints.
- To identify, formulate, and solve real network problems with FACTS controllers

**Overview**

| **Module 1** |
|---|
| • Advanced solid state devices: MOSFETs, IGBT, GTO, IGCT etc.<br>• Power modules, intelligent power modules. |
| **Module 2** |
| • Non-isolated dc-dc converters: Buck, boost, buck-boost, Cuk, SEPIC, Zeta in DCM and CCM.<br>• Isolated dc-dc converters: Flyback, forward, Cuk, SEPIC, Zeta, half bridge, push-pull and bridge in DCM and CCM.<br>• Single-phase, single-stage converters (SSSSC), power factor correction at ac mains in these converters. |
| **Module 3** |
| • Single-phase improved power quality ac-dc converters: Buck, boost, buck-boost, PWM VSC (Voltage source converters), multilevel VSCs, PWM CSC (Current voltage source converters).<br>• Three-phase improved power quality ac-dc converters: VSC, multilevel VSCs, multipulse VSCs, PWM CSC (Current voltage source converters).<br>• Multipulse ac-dc converters: Diode and thyristor based converters. |
| **Module 4** |
| • Power quality mitigation devices: Passive filters, active filters, hybrid filters.<br>• DTSTCOM (Distribution static compensator), DVR (Dynamic voltage restorer) and UPQC (Universal power quality conditioner). |
| **Module 5** |
| • SVC and STATCOM:<br>• Static Series Compensators(TSSC,TCSC, SSSC)<br>• Static Voltage and Phase Angle Regulators (TCVR and TCPAR).<br>• Combined Compensators (UPFC,IPFC) |

**Recommended Reading**

1. Narain G. Hingorani and Laszlo Gyugyi, “Understanding FACTS – Concepts and Technology of Flexible AC Transmission Systems”, Standard Publishers, New Delhi, 2001.
2. R. Mohan Mathur and Rajiv K. Varma, “Thyristor Based FACTS Controller for Electrical Transmission Systems”, Wiley Interscience Publications, 2002
3. Narain G. Hingorani, “Flexible AC Transmission”, IEEE Spectrum, April 1993, 40-45
4. Narain G. Hingorani, “High Power Electronics in Flexible AC Transmission”, IEEE Power Engineering Review, 1998
5. Elinar V. Larsen, Juan J Sanchez – Gasca Joe H. Chow, “Concepts for design of FACTS controllers to damp power swings”, IEEE Transactions on Power Systems, Vol. 10, No. 2, May 1995

| Programme Name | M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER I |
|---|---|
| **Course Code** | **EE5154T** |
| **Course Title** | ***PROGRAM ELECTIVE COURSE 2***<br>**RENEWABLE ENERGY SYSTEMS** |

**COURSE OBJECTIVES**

- To study the geometric positioning of PV system to get maximum output and also getting acquainted with PV materials.
- To study the geometric positioning of Wind Power Plant system to get maximum output with detail component study.
- To study the possible integration of the renewable energy systems with existing grid.

**COURSE OUTCOMES**

- Able to analyze the best conditions for solar PV systems, design the components with knowledge of PV materials.
- Able to analyze the best conditions for Wind Power Systems, components and the Electrical Systems.
- Renewable energy integration with existing grid.

**Overview**

| **Module 1** |
|---|
| Solar Radiation: Solar Spectrum, Extra-terrestrial radiation, Radiation on the earth surface, Global, diffuse solar radiation, Solar radiation at a given location, Daily radiation pattern, Annual variation in solar radiation, Optimal tilt for solar equipment, Monthly averaged global radiation at optimal tilt. |
| **Module 2** |
| Design of Solar cells: Upper limits of cell parameters, Losses in solar cell, solar cell design, design for high short circuit current, design for high open circuit voltage |
| **Module 3** |
| Solar cell technology: Si Wafer based solar cell technology: Development of commercial Si solar cells, high efficiency Si solar cells.<br>Thin Film Solar Cell Technologies: advantages, materials, deposition techniques, common features, types of thin film cell technologies. |
| **Module 4** |
| Concentrator PV cells and systems: Light Concentration, Series Resistance Optimization of Concentrator Cells, Optics for Concentrator PV |
| **Module 5** |
| **Emerging Solar Cell Technologies and** concepts: Organic Solar Cells, Dye-sensitized Solar Cell, GaAs solar cells, Thermo-Photovoltaics |
| **Module 6** |
| **Wind Energy**: Wind flow, Motion of wind, Vertical wind speed variation, Distribution of wind speeds, Power in the wind , Conversion of wind power, Wind turbines |
| **Module 7** |

| |
|---|
| **Components of Wind Power Plants**: Rotor, Nacelle, Towers, Electric Substation |
| **Module 8** |
| **Working of Wind Power Plants**: Physical Principle of Modern wind Turbine, Wind Turbine Rotor Blade Characteristics, Hub and main shaft functions, working of Geared, Direct-drive and hybrid WPP |
| **Module 9** |
| **Types of Generators**: WPP with Squirrel cage Induction Generator, Wound rotor Induction Generator, Doubly fed Induction Generator, Wound Rotor Synchronous Generator and Permanent Magnet Synchronous Generator. |
| **Module 10** |
| **Grid Integration of Wind Power Plants**: Direct, Indirect and mesh Grids, Integration and operational issues. |
| **Module 11** |
| Hydro Power: Small and Micro Hydro Power Plants. |

**Recommended Reading**


1. Chetan Singh Solanki, Solar Photovoltaics: Fundamentals, Technologies and Applications, PHI publication, Second edition.
2. Joshua Earnest and Tore Wizelius, Wind Power Plants and Project Development, PHI publication
3. Solar Energy International , Photovoltaics: Design and Installation Manual, New Society Publishers
4. Brendan Fox, Wind Power Integration: Connection and System Operational Aspects, The Institution Of Engineering And Technology

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|---|---|
| **Programme Name** | **M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER I** |
| **Course Code** | **EE5154P** |
| **Course Title** | **RENEWABLE ENERGY SYSTEMS LAB** |

**COURSE OBJECTIVES**

- To study the geometric positioning of PV system to get maximum output and also getting acquainted with PV materials.
- To study the geometric positioning of Wind Power Plant system to get maximum output with detail component study.
- To study the possible integration of the renewable energy systems with existing grid.

**COURSE OUTCOMES**

- Student shall perform experiments to measure the parameters of the PV module, also estimate efficiency of the PV system.
- Student shall be able to simulate the hybrid PV, Wind system and its integration to the grid.

**Overview**

1. Identifying and Measuring the parameters of a solar PV module in the Field
2. Series and Parallel connection of PV module
3. Estimating the effect of Sun tracking on Energy generation by Solar PV modules
4. Efficiency measurement of standalone solar PV system
5. Dark and illuminated current voltage characteristics of solar cell
6. Solar cells connected in series and parallel
7. Dependence of solar cell I-V characteristics on light intensity and temperature
8. Carrier lifetime measurements for a solar cell
9. Spectral Response measurement
10. Programming for wind power plant working and simulation
11. Programming for integration of solar and wind power systems and simulations

| Programme Name | M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER I |
|---|---|
| **Course Code** | **EE5155T** |
| **Course Title** | ***PROGRAM ELECTIVE COURSE 2*** <br> **HIGH VOLTAGE ENGINEERING** |

**COURSE OBJECTIVES**

- Strengthening the basics of electro statics, electro dynamics and travelling wave theory.
- Application of electric field intensity to solid, liquid, gaseous, vacuum dielectrics &their breakdown phenomenon.
- Enrich them about the HV testing methods as per IS/IEC standards
- To expose them to the techniques and need of measuring systems

**COURSE OUTCOMES**

- Introduces the fundamentals of electro static and electromagnetic fields and waves and its application to understand the breakdown of insulation, testing and measuring methods for HV/EHV power equipments.

**Overview**

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|---|
| **Module 1** |
| Laws of Electricity and Magnetism |
| **Module 2** |
| Concepts of capacitance, inductance and resistance |
| **Module 3** |
| Maxwell's Equations |
| **Module 4** |
| Wave travel through dielectric and conducting media |
| **Module 5** |
| Uniform and non-uniform electric fields, coefficient of uniformity |
| **Module 6** |
| High Voltage Generation |
| **Module 7** |
| Marx Generators |
| **Module 8** |
| High Voltage measurement |
| **Module 9** |
| Breakdown of gaseous dielectrics |
| **Module 10** |
| Breakdown of solids, liquids and Vacuum |

**Recommended Reading**

1. Electromagnetic Engineering: William Hayt
2. Engineering Electromagnetics: John D, Kraus
3. High Voltage Insulation Engineering: Ravindra Aurora

4. High Voltage Engineering: C. L. Wadhwa
5. High Voltage Engineering: Kamraj and Naidu
6. High Voltage Engineering: Kuffel E &Zaengl W S.
7. The Feynman Lectures on Physics – Vol-2: Feynman, Leyton, Sands

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|---|---|
| **Programme Name** | **M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER I** |
| **Course Code** | **EE5155T** |
| **Course Title** | **HIGH VOLTAGE ENGINEERING LAB** |

**COURSE OBJECTIVES**

- To demonstrate the breakdown phenomenon of discharges in solids, liquids, gases, generation of high voltage, measurement techniques and safety aspects.

**COURSE OUTCOMES**

- Develops understanding about various aspects of High Voltage Laboratory, Safety, and knowledge of testing and measuring systems as per industrial specifications.

**Overview**

1. Measurement of insulation resistance of insulating materials by megger (Analog and Digital) with different applied voltage and observe leakage current.
2. Power frequency withstand test on 11KV PT, 1600/5 amp CT
3. Study of corona discharge
4. Determination of insulating break-down strength of solid, liquid and gaseous dielectric media.
5. Power frequency high voltage withstand test on cable
6. Study of impulse generator.
7. Dry & Wet power frequency withstand test in insulator
8. Flash over test on insulator.
9. Double voltage double frequency withstand test on insulator.
10. Study of calibration of sphere gap.
11. Study of 100KV high voltage testing set.

| Programme Name | M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER I |
|---|---|
| **Course Code** | **EE5156T** |
| **Course Title** | ***PROGRAM ELECTIVE COURSE 2*** **DIGITAL SIGNAL PROCESSING** |

**COURSE OBJECTIVE**

- To create a thorough understanding of time and frequency domain concepts which are fundamental to all DSP technique.
- To create a thorough understanding of the different algorithms for analysis of signals.
- To provide a thorough understanding about feature extraction, classification and identification using different techniques.

**COURSE OUTCOME**

- Students should be masters in analyzing discrete-time signals in the time domain and frequency domain, using different transforms
- Students should be able to model various random signals.
- Students should be able take up advanced courses and do projects in signal processing and its applications

## Overview

| **Module 1** |
|---|
| Introduction: Various signal and system representation and manipulations, Sampling and Reconstruction of continuous time signals. |
| **Module 2** |
| Analysis of Linear Time Invariant Systems, Characteristics, Impulse Response, Convolution |
| **Module 3** |
| Z-transform: Properties of the z-transform, System functions, Poles and zeros. |
| **Module 4** |
| Frequency domain Analysis: Discrete Fourier series, Discrete Fourier transform and properties, Fast Fourier transform. |
| **Module 5.** |
| Multirate signal processing : decimation and interpolation |
| **Module 6** |
| Introduction to wavelets |
| **Module 7** |
| Spectral Estimation: Random processes, power spectral density (PSD) estimation, parametric and non-parametric models |
| **Module 8** |
| Introduction to Artificial Neural Network (ANN), Radial Basis Function (RBF) and State Vector Machine (SVM) |

**Recommended Reading**


1. Digital Signal Processing: Principles, Algorithms and Applications (4th Edition), John G. Proakis, Dimitris G. Manolakis, and D Sharma, Pearson Education In
2. Discrete-Time Signal Processing (Second Edition), Alan V. Oppenheim, Ronald W.
3. S. J. Mitra Digital Signal Processing: A Computer-Based Approach, 4th ed., McGraw-Hill
4. K. P. Soman& K I Ramachandran " Insights into Wavelets : from theory to practice

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|---|---|
| **Programme Name** | **M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER I** |
| **Course Code** | **EE5156P** |
| **Course Title** | **DIGITAL SIGNAL PROCESSING LAB** |

**COURSE OBJECTIVES**

- This course will provide a brief knowledge about MATLAB and its applications in the area of signal processing.
- To have a practical understanding of the different algorithms for analysis of signals.
- To practically implement different techniques of feature classification.

**COURSE OUTCOMES**

- Students should be able to apply the different transforms for the characterizations of signals and systems.
- Students should be able to model various random signals.
- Students should be able take up projects in signal processing and its applications.

**Overview**

1. Characterization of LTI systems
2. Frequency response of the given Transfer function.
3. Obtaining DTFT, FFT of discrete time signals.
4. Decimation and Interpolation
5. Modeling random Process
6. Implementation of ANN
7. Implementation of RBF
8. Implementation of SVM

| Programme Name | M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER II |
|---|---|
| **Course Code** | **EE5005S** |
| **Course Title** | **RESEARCH METHODOLGY (GENERIC CORE)** |

**COURSE OBJECTIVE**

- To develop understanding of the basic framework of research process, various research designs and techniques.
- To identify various sources of information for literature review and data collection.
- To develop an understanding of the ethical dimensions of conducting applied research.

**COURSE OUTCOME**

- Understand research terminology.
- Be aware of the ethical principles of research, ethical challenges and approval processes.
- Describe quantitative, qualitative and mixed methods approaches to research.
- Identify the components of a literature review process
- Critically analyse published research

**Overview**

| **Module 1: Motivation and importance of research methodology** |
|---|
| • Why research needs to be done<br>• What is research<br>• Research problem formulation<br>• Literature survey<br>• Analysis of the problem<br>• Experimental evaluation of the problem<br>• Survey techniques<br>• Statistical analysis |
| **Module 2: Presentation of the reports** |
| • Writing of short and long abstracts<br>• Writing and format of international and national journal papers<br>• Report writing |
| **Module 3: Presentation skill** |
| • English writing and communication skills<br>• Power point and other presentation skills |
| **Module 4: Statistics** |
| • Concept of mean mode median arithmetic mean, geometric mean, harmonic mean etc<br>• Probability and problem solving<br>• Distributions: Gaussian, chi-square, student-t distribution<br>• Design of experiment<br>• Hypothesis, testing and identification<br>• Problems on hypothesis testing |

**Recommended Reading**

1. Research Methodology: Methods and Techniques: C.R. Kothari

| Programme Name | M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER II |
|---|---|
| **Course Code** | **EE5054S** |
| **Course Title** | **RESTRUCTURED POWER SYSTEM** |

**COURSE OBJECTIVE**

- To learn overview of the restructured industry and the associated issues
- To Learn Concepts from Economics: Consumers and producers, Supply Demand, Electricity as commodity ,market equilibrium, introduction to different market mechanisms, competition and market power
- Understand Peculiarities of electricity trading, overview of different electricity markets
- Basic ancillary services, Need and procurement of ancillary services
- Strategic Bidding methodologies, FTRs, Power Trading in India, Electricity Markets Across the Globe

**COURSE OUTCOME**

- Upon successful completion of this course the students will be able to understand Background, overview of the restructured industry and the associated issues
- Upon successful completion of this course the students will be able to learn Restructuring Basic Concepts from Economics: Models for consumers and producers, market equilibrium, introduction to different market mechanisms, competition and market power
- Upon successful completion of this course the students will be able to understand Peculiarities of electricity as a commodity, models for competition and trading in the electricity sector, overview of different electricity markets
- Upon successful completion of this course the students will be able to understand need of ancillary services, ancillary services for supply-demand balance, voltage control and black-start, procurement of ancillary services
- Upon successful completion of this course the students will be able to understand Strategic Bidding methodologies, FTRs, Power Trading in India, Electricity Markets Across the Globe

**Overview**

| **Module 1: Introduction to Restructuring** |
|---|
| Background, overview of the restructured industry and the associated issues. |
| **Module 2: Basic Concepts from Economics** |
| Models for consumers and producers, market equilibrium, introduction to different market mechanisms, competition and market power. |
| **Module 3: Markets for Electricity** |
| Peculiarities of electricity as a commodity, models for competition and trading in the electricity sector, overview of different electricity markets. |
| **Module 4: Transmission Congestion Management** |

| |
|---|
| Understanding congestion and its impacts, congestion management schemes based on OPF and other methods, and their comparisons. |
| **Module 5: Locational Marginal Pricing** |
| Mathematical background, fundamentals of locational marginal pricing, LMP calculation methods. |
| **Module 6: Ancillary Services** |
| Definition of ancillary services, ancillary services for supply-demand balance, voltage control and black-start, procurement of ancillary services. |
| **Module 7: Transmission Pricing** |
| Rolled in schemes, marginal pricing schemes and comparative assessment. |
| **Module 8: Strategic Bidding Methodologies** |
| **Module 9: Introduction to FTRs** |
| **Module 10: Power Trading in India** |
| **Module 11: Electricity Markets Across the Globe** |

**Recommended Reading**

1. Fundamentals of Power System Economics by Daniel Kirschen and Goran Strbac
2. Electrical Power Trading by Sally Hunt

| Programme Name | M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER II |
|---|---|
| Course Code | EE5055T |
| Course Title | POWER SYSTEM STABILITY |

**COURSE OBJECTIVE**

- To develop linear and nonlinear models of multi-machine power systems
- To discuss the structure of modern power systems, the different levels of control, and the various types of stability properties of power systems.
- To detail the methodology behind the modal analysis on power system signals

**COURSE OUTCOME**

- The students shall be able to understand various power system stability issues
- The students shall be able to critically analyze the dynamic stability of power systems
- The students shall develop the ability to resolve stability and control related issues for modern power system

**Overview**

| **Module 1:Dynamic modeling of power system components for stability studies** |
|---|
| • Introduction : Classification and definitions of various stabilities defined in power system operation<br>• Synchronous generator dynamic model<br>• Multimachine dynamic modelling<br>• Effect of machine model used<br>• Modelling of FACTS devices<br>• Power system network modelling<br>• Load modelling and its impact |
| **Module 2: Small-signal stability** |
| • State-space representation and Stability of a dynamic system<br>• Linearization<br>• Eigen properties of the state matrix<br>• Model shape and sensitivity and participation factor<br>• Controllability and observability<br>• The concept of the complex frequency<br>• Relationship between Eigen properties and transfer functions<br>• Small-signal stability of a single machine infinite bus system (SMIB)<br>• Small signal stability of Multimachine system |
| **Module 3: Transient Stability** |
| • Elementary view of transient stability<br>• Equal area criteria<br>• Numerical integration methods<br>• Simulation of power system dynamic response<br>• Case study of transient stability of a large system |
| **Module 4: Voltage Stability** |
| • What is voltage stability / definition |

- Critical voltage and critical power relations with PV and QV curves
- Various types of bifurcations (definition of Hopf and complex bifurcation )
- Continuation power flow

**Recommended Reading**


1. P. Kundur, Power System Stability and Control: Tata McGraw-Hill, 2007.
2. P. Saure and M. A. Pai, Power System Dynamics and Control: Prentice Hall, Upper Saddle River, New Jersey 0758, 2002.
3. S. J. Mitra Digital Signal Processing: A Computer-Based Approach, 4th ed., McGraw-Hill.
4. S.R. Wagh, Power System Transient Stability Enhancement, Lambert academic publishing, 1st edition, 2013.

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|---|---|
| **Programme Name** | **M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER II** |
| **Course Code** | **EE5055P** |
| **Course Title** | **POWER SYSTEM STABILITY LAB** |

**COURSE OBJECTIVE**

- To develop linear and nonlinear models of multi-machine power systems
- To discuss the structure of modern power systems, the different levels of control, and the various types of stability properties of power systems.
- To detail the methodology behind the modal analysis on power system signals

**COURSE OUTCOME**

- The students shall be able to understand various power system stability issues by performing the power network simulation.
- The students shall be able to critically analyze the dynamic stability of power systems
- The students shall develop the ability to resolve stability and control related issues for modern power system

**Overview**

1. Power system modeling and load flow
2. Eigen value analysis of power system stability
3. Effect of change in mechanical input
4. Effect of fault clearing time
5. Effect of loss of one of the line
6. Effect of fault on one of the parallel transmission lines
7. Step-by-step method of solution of swing equations
8. Transient stability analysis for SMIB
9. Transient stability analysis for Multimachine
10. Enhancement of transient stability

| Programme Name | M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER II |
|---|---|
| Course Code | EE5008T |
| Course Title | SYSTEM IDENTIFICATION, ESTIMATION & FILTERING (Common for PS + CS) |

**COURSE OBJECTIVE**

- The objective of this course is to provide a broad theoretical basis for system identification, estimation, and learning.

**COURSE OUTCOME**

- Upon successful completion of this course student shall have thorough knowledge of least squares estimation, Kalman filters, function approximation theory, neural nets, radial basis functions, frequency domain analysis, maximum likelihood estimate, Cramer-Rao lower bound, Kullback-Leibler information distance, Akaike's information criterion.

**Overview**

| **Module 1:Estimation** |
|---|
| • Recursive Least Square (RLS) Algorithms<br>• Properties of RLS<br>• Random Processes, Active Noise Cancellation<br>• Discrete Kalman Filter-1<br>• Discrete Kalman Filter-2<br>• Continuous Kalman Filter<br>• Extended Kalman Filter |
| **Module 2: Representation and learning** |
| • Prediction Modeling of Linear Systems<br>• Model Structure of Linear Time-invariant Systems<br>• Time Series Data Compression, Laguerre Series Expansion<br>• Non-linear Models, Function Approximation Theory, Radial Basis Functions<br>• Neural Networks<br>• Error Back Propagation Algorithm |
| **Module 3: System Identification** |
| • Perspective of System Identification, Frequency Domain Analysis<br>• Informative Data Sets and Consistency<br>• Informative Experiments: Persistent Excitation<br>• Asymptotic Distribution of Parameter Estimates<br>• Experiment Design, Pseudo Random Binary Signals (PRBS)<br>• Maximum Likelihood Estimate, Cramer-Rao Lower Bound and Best Unbiased Estimate<br>• Information Theory of System Identification: Kullback-Leibler Information Distance, Akaike's Information Criterion |

**Recommended Reading**


1. Ljung, Lennart. *System Identification: Theory for the User*. 2nd ed. Upper Saddle River, NJ: Prentice-Hall, 1999.

2. Goodwin, Graham, and Kwai Sang Sin. *Adaptive Filtering, Prediction, and Control*. Englewood Cliffs, NJ: Prentice-Hall, 1984.
3. Burnham, Kenneth, and David Anderson. *Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach*. 2nd ed. New York, NY: Springer, 2003.
4. Brown, Robert, and Patrick Hwang. *Introduction to Random Signals and Applied Kalman Filtering*. 3rd ed. New York, NY: Wiley, 1996.

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| **Programme Name** | **M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER II** |
| **Course Code** | **EE5008P** |
| **Course Title** | **SYSTEM IDENTIFICATION, ESTIMATION & FILTERING LAB (Common for PS+CS)** |

**COURSE OBJECTIVE**

- The objective of this course is to provide a broad theoretical basis for system identification, estimation, and learning.

**COURSE OUTCOME**

- The student shall be able to design and implement various filters and controllers for engineering applications.

**Overview**

1. To find autocorrelation for a given function.
2. To implement KALMAN filter using Scilab.
3. To implement EKF using Scilab.
4. To implement UKF using Scilab.
5. To design learning controller.
6. To design adaptive controller.

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| **Programme Name** | **M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER II** |
| **Course Code** | **EE5161S** |
| **Course Title** | ***PROGRAM ELECTIVE COURSE 3***<br>**HIGH PERFORMANCE ELECTRIC DRIVES** |

**COURSE OBJECTIVE**

1. To explain the basic building blocks of high performance electrical drives.
2. To develop mathematical models of AC & DC machines & use these models for designing high performance drives
3. To impart a thorough understanding of power electronic converters for drives & controller design also.

**COURSE OUTCOME**

1. Students should be able to identify the various building blocks of electrical drives & suggest improvements /additions to make it a high performance drive
2. Students should be able to model AC & DC machines & use these models to evaluate the performance of drives.
3. Students should be able to design controllers for better parameter control in drives.

**Overview**

| **Module 1** |
|---|
| Introduction |
| **Module 2** |
| Modern Power Electronic Drives |
| **Module 3** |
| Permanent-Magnet Synchronous & Brushless DC Motor Drives |
| **Module 4** |
| Polyphase Induction Machines |
| **Module 5** |
| Frequency-controlled Induction Motor Drives |
| **Module 6** |

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|---|
| Vector-controlled Induction Motor Drives |
| **Module 7** |
| Space Vector Modulation |

**Recommended Reading**


1. R Krishnan, Electric Motor Drives Modelling Analysis and Control
2. B K Bose, Power Electronics for AC drives
3. G K Dubey, Electrical Drives
4. Power Electronics –Joseph Vidyathil

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|---|---|
| **Programme Name** | **M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER II** |
| **Course Code** | **EE5162S** |
| **Course Title** | ***PROGRAM ELECTIVE COURSE 3***<br>**POWER PLANT COMPONENT DESIGN** |

**COURSE OBJECTIVE**

1. To become familiar with power plant systems, terms and definitions and basic power plant engineering design calculations and application of power plant related equipment.
2. To study the standards utilized in the design and operation of power plant equipment.
3. Students will prepare and present topical issues relevant to power plant design and operations.

**COURSE OUTCOME**

1. Students will become familiar with power plant systems, terms and definitions and basic power plant engineering design calculations.
2. Students will become familiar with the proper design and application of power plant related equipment.
3. Students will become familiar with recognized standards utilized in the design and operation of power plant equipment.
4. Students will prepare and present topical issues relevant to power plant design and operations.

## Overview

| **Module 1: Resources and Development of power in India** |
|---|
| • Introduction<br>• Hydel power Development<br>• Thermal Power development<br>• Nuclear power development<br>• Enron power plant in Maharashtra<br>• Present power position in India<br>• Future planning in India |
| **Module 2: Design construction and operation of different components of hydroelectric power station** |
| • Reservoirs<br>• Dams<br>• Spillways and control gate<br>• Inlet and outlet works<br>• Water Tunnels<br>• Canals and Penstocks<br>• Water Hammer and surge tanks |

- Power house and turbine setting
- Prime movers
- Specific Speed Turbines
- Draft Tubes
- Model and Model testing
- Selection of Turbine

**Module 3: Introduction to thermal plant**

- General layout of modern thermal power plant
- Working of Thermal Power plant
- Site selection ,material requirements of 100MW plant
- Development of thermal power in India
- Fossil fuel resources and prospects of thermal plant in India

**Module 4: Fuels properties and their storage**

- Analysis of coal
- Basic coal ingredients and their effects on furnace design
- Coal beneficiation, coal blending
- Indian coals
- Selection of coal for thermal power plants
- Liquid fuels, Gaseous fuels, Coal fines as fuels
- Oil shale and Tar sands

**Module 5 :Coal handling ,storage, preparation & Feeding**

- In-plant and out-plant handling of coal
- Storage of coal at plant site
- Coal dust and its control, coal crushing, coal weighing methods

**Module 6: Draught System**

- Losses in the Air Gas Loop System and its measurements.
- Natural Draught and Design of Chimney
- Artificial Draught, Forced Draught, Induced Draught
- Comparison Of induced and Forced Draught

**Module 7: High Pressure Boilers**

- Types and advantages of high-pressure boiler
- Location of furnace wall and boiler design
- Effect of domestic coal on boilers
- Cause of boiler failures

**Module 8: Steam Turbines**

- Classification of steam turbines
- Working of steam turbines
- Compounding of steam turbines
- Advantages and disadvantages of steam turbines
- Turbine troubles

**Module 9: Condensers**

- Elements of the steam condenser

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|---|
| • Types of steam condensers<br>• Thermodynamic analysis of steam condensers<br>• Corrosion and scale formation in condenser tubes and their prevention<br>• Materials for steam condensers. |
| **Module 10: Cooling ponds and cooling towers** |
| • Necessity of cooling the condenser water<br>• Condenser water cooling system<br>• Water cooling methods and Mechanics of cooling, introduction to cooling ponds<br>• Different types of cooling tower<br>• Performance of cooling towers and methods to improve it.<br>• Cooling towers environmental effects<br>• Water treatment system for cooling tower and cooling pond |
| **Module 11: Feed Water Treatment** |
| • Necessity of feed water treatment<br>• Different impurities in water, Effects of impurities<br>• pH value of water and its Importance<br>• Different methods of water treatments<br>• Internal and external treatment system.<br>• RO, Sea water treatment, Nuclear reactor and importance of water purity |
| **Module 12: Power plant layouts** |
| • General design of power plans<br>• Architectural features<br>• Inline arrangements of units<br>• Units in parallel and perpendicular to division wall<br>• One room one floor station, Unit plan station, Outdoor type steam electric station,<br>• Lighting of steam power plants. |

**Recommended Reading**

| Programme Name | M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER II |
|---|---|
| **Course Code** | **EE5163S** |
| **Course Title** | ***PROGRAM ELECTIVE COURSE 3*** <br> **HIGH VOLTAGE TRANSMISSION SYSTEM** |

**COURSE OBJECTIVE**

1. To introduce the HVDC and EHVAC transmission technology and its advantages (and disadvantages) over conventional AC transmission.

**COURSE OUTCOME**

1. The students would be able to appreciate the advantages (and disadvantages) of using HVDC for bulk power transmission over HVAC.
2. The students shall be able to design converter and inverter operations.
3. The students shall be able to understand the AC Extra high voltage AC Transmission system.

**Overview**

| **Module 1:Introduction** |
|---|
| DC Power Transmission Technology: Introduction, comparison of AC & DC transmission, application of DC transmission, Description of DC transmission systems, planning & modern trends. |
| **Module 2: Analysis of HVDC Converters** |
| 3-pulse, 6-pulse,12-pulse converters , converters station and terminal equipment commutation process, rectifier & inverter operation, equivalent circuit for converters, simplified analysis of Graetz circuit Control of Converters |
| **Module 3:HVDC System Control** |
| Firing angle control, Current and extinction angle control, starting and stopping of DC link, power control, higher level Controllers, Converter faults and protection: Introduction, Converter faults, protection against over current, over voltage in a converter station, surge arrestors. Smoothing reactor, Harmonics and filters. |
| **Module 4: Multi Terminal DC Systems** |
| Potential applications of MTDC systems, types of system, operation & control and protection of MTDC systems. Parallel operation of HVDC and HVAC. |
| **Module 5 : Introduction to EHVAC transmission** |
| Transmission line trends and preliminary aspects. Standard transmission voltage-power handling capacities and line losses mechanical aspects. |
| **Module 6:Over-Voltages in EHV system** |
| Switching operation, interruption of inductive current, capacitive current, Ferro-Resonance over |

**Recommended Reading**


1. PrabhaKundur, Power system Stability & Control, Tata McGraw Hil Edition
2. Padiyar K.R., HVDC Transmission Systems, 1 st Ed., Wiley Eastern Ltd., 19 1
3. Kimabrk E.W., HVDC Transmission, 1st Ed., Wiley,1965
4. Rakosh Das Begamudre, Extra High Voltage A.C. Transmission Engineering, New Age International, 2006

| Programme Name | M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER II |
|---|---|
| **Course Code** | **EE5164T** |
| **Course Title** | ***PROGRAM ELECTIVE COURSE 4***<br>**INSULATION SYSTEM DESIGN** |

**COURSE OBJECTIVE**

1. To understand the impact of High Voltage surge on a machine coil and the relation between turn to turn and inter turn insulation to get an idea of importance of insulation design
2. To understand the mathematical aspects and apply the finite element methods to simple insulation geometry
3. Give a glimpse of CO-OB4: Condition monitoring and assessment of transformers and rotting machines
4. Design of earth mat for an EHV substation

**COURSE OUTCOME**

1. With this subject the student will understand the importance of insulation and the effect of surge on the insulation and is of prime importance in design of EHV transformers and rotating machines.

**Overview**

| **Module 1** |
|---|
| Insulating materials for various electrical machines |
| **Module 2** |
| Design of capacitance to ground and inter-turn capacitance for machine coil and their significance in design of machines. |
| **Module 3** |
| Condition Monitoring and assessment of transformers and rotating Machines: (a) Partial discharge, (b) Frequency response analysis, (c) tan delta and IR tests (d) Impulse response analysis etc. |
| **Module 4** |
| Finite element method and its application to EM field design |
| **Module 5** |
| Earthing grid design as per IEEE Std. 80 |
| **Module 6** |
| Design of transformer |

**Recommended Reading**


1. Surge phenomena in electrical machines by Bedrich Heller, A.
2. M Tech Thesis on Earthing in Substation by Nilesh Thakur
3. Traveling Wave Phenomena by Bewli
4. IEEE Standard 80

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|---|---|
| **Programme Name** | **M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER II** |
| **Course Code** | |
| **Course Title** | **INSULATION SYSTEM DESIGN LAB** |

**COURSE OBJECTIVE**

1. To understand the impact of High Voltage surge on a machine coil and the relation between turn to turn and inter turn insulation to get an idea of importance of insulation design
2. To understand the mathematical aspects and apply the finite element methods to simple insulation geometry

**COURSE OUTCOME**

1. The student shall be able to design the models in software and perform field analysis of the insulation system.

**Overview**

1. To find capacitance of given geometry and potential distribution in dielectric using FEMM.
2. To determine capacitance between two spheres.
3. To find the voltage distribution in the air bubble in transformer oil.
4. To find capacitance of three core cable.
5. To analyze magnetic flux density plot and calculate inductance of the coil.
6. To find inductance of gapped inductor.
7. To find leakage inductance of transformer.
8. To find the voltage distribution in the Air and Transformer Oil
9. To compare calculations of Force versus Position for a solenoid plunger with experimental results.

| Programme Name | M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER II |
|---|---|
| Course Code | EE5165T |
| Course Title | *PROGRAM ELECTIVE COURSE 4*<br>CYBER SECURITY FOR SMART GRID |

**COURSE OBJECTIVE**

1. To study various information and communication technologies for smart grid.
2. To study information security for the smart grid and its standards.
3. To study Security Threats, Vulnerabilities and Cryptography.

**COURSE OUTCOME**

1. After successful completion of this course student shall be able to understand the various communication threats to smart grid and its security.

**Overview**

| **Module 1: Information and Communication Technologies** |
|---|
| Introduction, dedicated and shared communication channels, switching techniques (circuit switching, message switching, packet switching), communication Channel (Wired communication, optical fiber, radio communication, cellular mobile communication, satellite communication), layered architecture and protocols (ISO/OSI model, TCP/IP) |
| **Module 2: Communication Technologies for the Smart Grid** |
| Introduction, communication technologies (IEEE 802 series, mobile communication, and multiple protocol label switching, power line communication), standards for information exchange (standards for smart metering, modbus, DNP3, IEC 61850). |
| **Module 3: Information Security for the Smart Grid** |
| Introduction, encryption and decryption (symmetric key encryption, public key encryption), authentication (Authentication based on shared secrete key, authentication based on key distribution centre), digital signatures (Secrete key signature, public key signature, message digest), Cyber Security Standards (IEEE 1686: IEEE standard for substation intelligent electronic devices (IEDs) cyber security capabilities, IEEE 62351: Power system management and associated information exchange-data and communications security). |
| **Module 4: Standards and Cyber Security** |
| Standards (approach to smart grid interoperability standards), smart Grid Cyber Security (Cyber security state of the art, cyber security risks, cyber security concerns associated with AMI, mitigation approach to cyber security risks), cyber Security and possible operation for improving methodology for other users. |
| **Module 5: Information Security Concepts** |
| Information Security Overview, Information Security Services, types of attacks, goals for security, E-commerce security, computer forensics, steganography, Security Engineering |
| **Module 6: Security Threats, Vulnerabilities and Cryptography** |
| Overview of Security threats, Insecure Network connections, Information Warfare and Surveillance, Introduction to Cryptography, Symmetric key Cryptography, Asymmetric key Cryptography, and Applications of Cryptography. |

**Recommended Reading**


1. Smart Grid: Fundamentals of Design and Analysis, Wiley Publications
2. JanakaEkanayake: Khithisri Layanage: Jiyanage Wu: Akihiko Yokoyama: Nick Jenkins, Smart Grid: Technology and Applications, Wiley Publications.

| Programme Name | M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER II |
|---|---|
| Course Code | |
| Course Title | CYBER SECURITY FOR SMART GRID LAB |

**COURSE OBJECTIVE**

1. To study various information and communication technologies for smart grid.
2. To study information security for the smart grid and its standards.
3. To study Security Threats, Vulnerabilities and Cryptography.

**COURSE OUTCOME**

1. The student shall be able to study various hacking techniques and cyber security related issues in smart grid.

**Overview**

1. Basics of networking
2. Introduction to Cryptography
3. Overview of Security threats
4. Types of Security Attacks
5. Hacking Techniques
6. Cyber-crime and Cyber terrorism

| | |
|---|---|
| **Programme Name** | **M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER II** |
| **Course Code** | **EE5166T** |
| **Course Title** | ***PROGRAM ELECTIVE COURSE 4***<br>**SUBSTATION AUTOMATION** |

**COURSE OBJECTIVES**

1. To Gain knowledge of state-of-the-art Substation Automation technologies.
2. To learn the levels of integration and automation that can be incorporated into new or existing substations.
3. To learn available system architectures, IED characteristics and protocols, and industry standards.
4. To learn how SCADA can be designed for integration with other systems.

**COURSE OUTCOME**

1. The student shall earn the knowledge of state-of-the-art Substation Automation Technologies.
2. The student shall learn how to design SCADA integration with other systems.

**Overview**

| **Module 1:Introduction** |
|---|
| • Introduction<br>• Classification |
| **Module 2: Substation equipment** |
| • High voltage switching equipment<br>• High voltage power electronic substations |
| **Module 3: Substation design** |
| • Introduction<br>• Bus bars for Outdoor Yards<br>• Corona Rings, and Corona Bells<br>• Mechanical Stresses and Factor of Safety for Support Insulators<br>• Clamps and Connectors for EHV<br>• Conductors, Bundled Conductors<br>• Pollution Behavior of Insulators and Insulation Levels<br>• Clearance<br>• Station Earthing System, Earthed Screens<br>• Corona and Audible Noise<br>• Electric Field at Working Level. |
| **Module 4** |
| • Interface between automation and the substation |

| |
|---|
| • Substation Integration and Automation |
| **Module 5: SCADA** |
| • Introduction to Supervisory Control and Data Acquisition.<br>• SCADA Functional requirements and Components.<br>• General features, Functions and Applications, Benefits.<br>• Configurations of SCADA, RTU (Remote Terminal Units) Connections.<br>• Power Systems SCADA and SCADA in Power System Automation.<br>• SCADA Communication requirements.<br>• SCADA Communication protocols: Past Present and Future.<br>• Structure of a SCADA Communications Protocol. |

**Recommended Reading**


1. D.P.Kothari, Nagrath, "Modern Power System Analysis", 4th edition, Tata McGraw Hill, New Delhi 2011.
2. A.J.Wood, B.F. Woolenberg, "Power System Operation and Control", 2nd Edition, John Wiley & sons, Inc 1996 .
3. J.D. McDonald &L.L.Grigsby, "Electrical Power Substation Engineering", CRC Press LLC 2003.
4. James Northcote-Green, Robert Wilson, "Control and Automation of Electrical Power Distribution Systems", CRC Press, 2006.
5. James A. Mohmoh, "Electrical Power Distribution, Automation, Protection and Control", CRC Press, 2007

| Programme Name | M. Tech. (Electrical Engineering with specialization in Power Systems), SEMESTER II |
|---|---|
| **Course Code** | |
| **Course Title** | **SUBSTATION AUTOMATION LAB** |

**COURSE OBJECTIVES**

1. To Gain knowledge of state-of-the-art Substation Automation Technologies
2. To learn the levels of integration and automation that can be incorporated into new or existing substations.
3. To learn available system architectures, IED characteristics and protocols, and industry standards.
4. To learn how SCADA can be designed for integration with other systems

**COURSE OUTCOME**

1. The student shall be able to simulate fault scenarios.
2. The student shall be able to develop automation scheme using PLC

**Overview**

1. Circuit Breaker Status Indication from field input
2. Fault scenario simulation in a feeder
3. Fault scenario simulation in a Transformer /Bus
4. Control Of Bus Voltages Through Onload Tap Changes
5. Development of 11KV/433 volts substation automation scheme using PLC for normal load operation
6. Autoreclosure Operation