# Course Curriculum

***for***

# Master of Technology Programme

***in***

# Power Electronics and Power Systems

**Department of Electrical and Electronics Engineering**

# National Institute of Technology Goa

**Farmagudi, Ponda, Goa - 403 401**

# Semester-wise Credits Distribution

| Semester | Total Credits |
|---|---|
| I | 12+4+2=18<br>(4-Programme Core + 2-Labs+1-Seminar) |
| II | 9+3+4+2=18<br>(3-Programme Core +1-Elective+ 2-Labs+1- Viva) |
| III | 06+08 =14<br>(2-Electives + Major Project -I) |
| IV | 14<br>(Major Project Work-II) |
| **Total Credits** | **64** |

| M.Tech I – Semester | | | | |
|---|---|---|---|---|
| **Sl. No** | **Sub. Code** | **Subjects** | **L-T- P** | **Credits** |
| 1 | EE600 | Power Electronic Converters & Drives | 3-0-0 | 3 |
| 2 | EE601 | Machine Modeling & Analysis | 3-0-0 | 3 |
| 3 | EE602 | Advanced Power system Analysis | 3-0-0 | 3 |
| 4 | EE603 | Renewable Energy Systems | 3-0-0 | 3 |
| 5 | EE604 | Power Electronics Laboratory | 0-0-3 | 2 |
| 6 | EE605 | Simulation Laboratory | 0-0-3 | 2 |
| 7 | EE606 | Seminar | 0-0-3 | 2 |
| | | **Total Credits** | | 18 |

| M.Tech II – Semester | | | | |
|---|---|---|---|---|
| **Sl. No** | **Sub. Code** | **Subjects** | **L-T- P** | **Credits** |
| 1 | EE650 | Advanced Electric Drives | 3-0-0 | 3 |
| 2 | EE651 | HVDC & FACTS | 3-0-0 | 3 |
| 5 | EE652 | Systems & Control Theory | 3-0-0 | 3 |
| 3 | EE8xx | Elective-I | 3-0-0 | 3 |
| 4 | EE653 | DSP & FPGA Laboratory | 0-0-3 | 2 |
| 5 | EE654 | Electric Drives Laboratory | 0-0-3 | 2 |
| 6 | EE655 | Viva | | 2 |
| 7 | HU650 | Communication Skills and Technical Writing | 1-0-2 | 0 |
| | | **Total Credits** | | 18 |

| M.Tech III - Semester | | | | |
|---|---|---|---|---|
| **Sl. No** | **Sub. Code** | **Subjects** | **L-T- P** | **Credits** |
| 1 | EE8xx | Elective – II | 3-0-0 | 3 |
| 2 | EE8xx | Elective – III | 3-0-0 | 3 |
| 3 | EE700 | Major Project-I | 0-0-12 | 08 |
| | | **Total Credits** | | 14 |

| M.Tech IV- Semester | | | | |
|---|---|---|---|---|
| **Sl. No** | **Sub. Code** | **Subjects** | **L-T- P** | **Credits** |
| 1 | EE750 | Major Project-II | 0-0-21 | 14 |
| | | **Total Credits** | | 14 |

# List of Electives

| Program Electives | | | | |
|---|---|---|---|---|
| **SI. No.** | **Course Code** | **Course Name** | **Total Credit (L-T-P)** | **Credits** |
| | | **Elective-I** | | |
| 1 | EE 801 | Modelling and Simulation of Power Electronic Systems | 3(3-0-0) | 3 |
| 2 | EE 802 | Advanced Power Electronics | 3(3-0-0) | 3 |
| 3 | EE 803 | Photovoltaic and its Applications | 3(3-0-0) | 3 |
| | | **Elective-II** | | |
| 1 | EE 804 | Power System Dynamics & Control | 3(3-0-0) | 3 |
| 2 | EE805 | Smart Electric Grid | 3(3-0-0) | 3 |
| 3 | EE 806 | Power Quality | 3(3-0-0) | 3 |
| | | **Elective-III** | | |
| 1 | EE807 | Soft Computing | 3(3-0-0) | 3 |
| 2 | EE 808 | DSP Controlled Drives | 3(3-0-0) | 3 |
| 3 | EE 809 | Digital Control Theory | 3(3-0-0) | 3 |
| 4 | EE810 | Optimal Control | 3(3-0-0) | 3 |

# Course Contents

| Subject Code EE600 | Power Electronic Converters & Drives | Credits: 3 (3-0-0) Total hours: 45 |
|---|---|---|
| **Module 1** | | |
| Phase controlled converters: Single phase Half controlled and fully controlled converters, input power factor and harmonic factor, single phase dual converters, power factor Improvements. Three phase half controlled and fully controlled converters, evaluation of input power factor and harmonic factor and effect of input line inductance, power factor improvement, 12 pulse/18 pulse converter, dual converters, front end converter or synchronous link converters.<br>Basic power electronic drive system and components, Different types of loads, shaft-load coupling systems. Stability of power electronic drive. Torque-speed characteristics of converter controlled separately excited dc motor in continuous and discontinuous mode of conduction. | | |
| **Module 2** | | |
| DC-DC converters: Study of Class - A, B, C, and D choppers, non-isolated and isolated DC-DC converters. Separately excited DC motor drive using DC-DC converters, four quadrant operation, dynamic and regenerative braking. | | |
| **Module 3** | | |
| Inverters: single phase inverters, three phase inverters, pulse width modulation techniques, multi-level inverters. | | |
| **Module 4** | | |
| Induction to motor drives: Equivalent circuit, speed control, slip power recovery schemes. Synchronous motor drives: Operation with fixed frequency and variable frequency source. Closed-loop control of drives: D.C drives, A.C. Drives. | | |
| **Reference books** | 1. M.H. Rashid: Power Electronics-circuits, Devices and Applications, 3rd Edition, PHI, 2005.<br>2. Ned Mohan, T.M. Undeland and William P. Robbins: Power Electronics: Converters, Applications, 3rd Edition, John Wiley & Sons, 2009<br>3. S.B. Dewan, Gordon R. Slemon and A. Straughen: Power Semiconductor Drives, John Wiley Pub.,1996.<br>4. B.K. Bose: Modern Power Electronics and AC Drives, 1st Edition, Pearson, 2002.<br>5. Philip T. Krein: Elements of Power Electronics, Oxford University Press.<br>6. John G. Kassakian, Martin F. Schlect, Geroge C. Verghese: Principles of Power Electronics , Pearson Education.<br>7. R. Krishnan: Electronic motor drives modeling Analysis and control I Edition Prentice Hall India. | |

| Subject Code EE601 | Machine Modelling & Analysis | Credits: 3 (3-0-0) Total hours: 45 |
|---|---|---|
| **Module 1** | | |
| Basic principles of electric machine analysis: Magnetically coupled circuits, Electro-magnetic (EM) energy conversion, Single and double excited systems. Machine windings and air-gap MMF, Winding inductances and voltage equations, Production of electromagnetic torque. | | |
| **Module 2** | | |
| Reference frame theory: Equations of transformation, transformation between reference frames, variables observed from various frames. Theory of symmetrical induction machines: Voltage and torque expression, state-space model of Induction motor in'd-q-0' variables. Computer simulation of arbitrary reference frame. | | |
| **Module 3** | | |
| Theory of synchronous machines: Voltage and torque equations, equations in arbitrary reference frame.Concept of sub-transients, transient armature inductances and field time constant, Operation of synchronous machine under asynchronous running, Hunting and small oscillations, Synchronizing and damping torques, equal area criteria, computer simulation. | | |
| **Module 4** | | |
| Field aspects of electrical machines: Vector potential, Classical two-dimensional analysis of air gap field. Field analysis and performance calculation in linear Induction motor and linear synchronous motor. Finite element method of calculation, vector potentials in machines and actual boundaries, magnetic saturation. | | |
| **Reference books** | 1. P. C. Krause, O. Wasynczuk and S.D. Sudhoff: Analysis of Electric Machinery and Drive Systems, 2nd Edition, IEEE Press, 2002.<br>2. J. Meisel: Principles of Electromechanical Energy Conversion, R.E. Krieger, 1984.<br>3. N. Bianchi: Electrical Machine Analysis using Finite Elements, CRC Press, 2005<br>4. P.S. Bhimbra: Generalized Theory of Electrical Machines, Khanna Publishers, 2006. | |

| Subject Code EE602 | Advanced Power System Analysis | Credits: 3 (3-0-0) Total hours: 45 |
|---|---|---|
| **Module 1** | | |
| Network Modelling: Formation of network matrices, Singular and non-singular Transformation. Algorithms for formation of bus admittance and bus impedance matrices with mutually coupled branches, Sparsity Technique and optimal ordering. | | |
| **Module 2** | | |
| Load flow: Load flow-Newton Raphson method, Decoupled ,Fast decoupled Load flow, Sensitivity factors,Multi area power flow analysis, ATC assessment, DC power flow model. | | |
| **Module 3** | | |
| Fault and Contigency Analysis: Balanced and unbalanced faults, Digital simulation techniques in fault analysis,Z Bus method in contingency analysis, Contingency Analysis of DC Model, System Reduction for Contingency and Fault Studies. | | |
| **Module 4** | | |
| Security and State Estimation:Security assessment, State Estimation in Power Systems, Maximum Likelihood Weighted Least-Squares Estimation, State Estimation of an AC Network, Detection and Identification of Bad measurements, Network Observability and Pseudo-measurements. | | |
| **Reference books** | 1. Stagg.G.W , El. Abiad.A.H: Computer Methods in Power System Analysis, McGra w Hill.<br>2. Kundur.P: Power System Stability and Control, McGraw Hill<br>3. Wood.A.J and Wollenberg.B.F: Power Generation Operation and Control, John Wiley and sons, New York.<br>4. D. P. Kothari and I. J. Nagrath: Modern Power System Analysis, Tata McGraw Hill Publishing Co. Ltd.<br>5. J. Arrilaga, C. P. Arnold, B. J. Harker: Computer Modelling of Electric Power System, John Wiley & Sons.<br>6. K.Mahailnaos, D. P. Kothari, S. I. Ahson: Computer Aided Power System Analysis & Control, Tata McGraw Hill Publishing Co. Ltd.<br>7. G. T. Heydt: Computer Analysis Methods for Power Systems, Macmillan Publishing Company, NewYork.<br>8. L. P. Singh: Advanced Power System Analysis and Dynamics, New Age International Publishers, New Delhi. | |

| Subject Code EE 603 | Renewable Energy Systems | Credits: 3 (3-0-0) Total hours: 45 |
|---|---|---|

**Module 1**

Non-renewable reserves and resources; renewable resources, Transformation of Energy.

Distributed Generation, renewable energy economics.

Solar Power: Solar processes and spectral composition of solar radiation; Radiation flux at the Earth's surface. Solar collectors. Types and performance characteristics.

Photo-Voltaic power plants: Solar energy, generation of electricity PV cell characteristic, Stand alone system with DC and AC loads with and without battery storage, Grid connected PV systems, Maximum Power Point Tracking

Fuel cells: Fuel cells, commercial and manufacturing issues, equivalent circuit, Applications.

**Module 2**

Wind Energy: Wind energy conversion, efficiency limit for wind energy conversion, types of converters, aerodynamics of wind rotors, power- speed and torque - speed characteristics of wind turbines, wind turbine control systems. conversion to electrical power: induction and synchronous generators, grid connected and self-excited induction generator operation, constant voltage and constant frequency generation with power electronic control, single and double output systems, reactive power compensation, characteristics of wind power plant, applications.

**Module 3**

Tidal Energy: Wave characteristics. Conversion systems and their performance features. Application. Geothermal energy: Biological conversion of Energy.

**Module 4**

Induction generators: operating principle, self-excited induction generator, speed and voltage control, performance analysis, semi variable speed induction generator, variable speed induction generators with full and partial rated power converter topologies, isolated systems, self excited induction generator

**Module 5**

Energy Storage systems: Parameters, lead-acid batteries, ultra-capacitors, flywheels, superconducting magnetic storage system, pumped hydroelectric energy storage, compressed air energy storage.

**Reference books**

1. S. N. Bhadra, D. Kastha, S. Banerjee: Wind Electrical Systems, Oxford Univ. Press, 2005.
2. S.A. Abbasi, N. Abbasi: Renewable Energy Sources and Their Environmental Impact, Prentice Hall of India,2004.
3. Felix A. Farret and M. Godoy Simões: Integration of Alternative Sources of Energy, John Wiley & Sons,2006.
4. R. Teodorescu, M. Liserre and Pedro Rodríguez: Grid Converters for Photovoltaic and Wind Power Systems, John Wiley & Sons, 2011.

| Subject Code EE604 | Power Electronics Laboratory | Credits: 2 (0-0-3) Total hours: 45 |
|---|---|---|
| 1) Single phase Half and Full controlled Converter with R-L and R-L-E loads.<br>2) Three-phase Half and Full controlled Converter with R-L and R-L-E loads.<br>3) Single phase AC voltage controller feeding R and R-L loads.<br>4) Characteristics of Power Semiconductor devices (SCR, Triac etc.).<br>5) DC-to-DC Switched Mode Converters.<br>6) 1- Φ & 3- Φ Inverter with square wave, quasi-square wave and SPWM Control | | |
| **Reference books** | 1. M.H. Rashid: Power Electronics-circuits, Devices and Applications, 3rd Edition, PHI, 2005.<br>2. Ned Mohan, T.M. Undeland and William P. Robbins: Power Electronics: Converters, Applications, 3rd Edition, John Wiley & Sons, 2009. | |

| Subject Code EE605 | Power Electronics Simulation Laboratory | Credits: 2 (0-0-3) Total hours: 45 |
|---|---|---|
| Modelling of DC-DC converters<br>Study of different PWM techniques<br>Study on the 'dq0' transformation in various frames of reference<br>Modelling of DC motor, Induction motor and synchronous motor drives | | |
| **Reference books** | 1. M.H. Rashid : Power Electronics-circuits, Devices and Applications, 3rd Edition, PHI, 2005.<br>2. Ned Mohan, T.M. Undeland and William P.Robbins: Power Electronics: Converters, Applications, 3rd Edition, John Wiley & Sons, 2009. | |

| Subject Code EE 606 | Seminar | Credits: 2 (0-0-3) |
|---|---|---|
| Students will have to choose a current research topic in Power Electronics and Power Systems related areas or industry practices and prepare a write up along with suitable presentation and demonstration. | | |

| Subject Code EE650 | Advanced Electric Drives | Credits: 3 (3-0-0) Total hours: 45 |
|---|---|---|
| **Module 1** | | |
| Basic power electronic drive system and components, Different types of loads, shaft-load coupling systems. Stability of power electronic drive.<br>Scalar and Vector control of Induction motor, Direct torque and flux control of Induction motor. | | |
| **Module 2** | | |
| Self-controlled synchronous motor drive, Vector control of synchronous motor drive. | | |
| **Module 3** | | |
| Switched reluctance motor drive, Brushless DC motor drive, Permanent magnet drives and Industrial drives. | | |
| **Reference books** | 1. B.K. Bose: Modern Power Electronics and AC Drives, 1st Edition, Pearson, 2002.<br>2. Bin-Wu: High-power Converters and AC Drives, IEEE Press, John Wiley & Sons, 2006<br>3. R. Krishnan: Electric Motor drives - Modelling, Analysis and Control, PHI India Ltd., 2002. | |

| Subject Code<br>EE 651 | HVDC and FACTS | Credits:3 (3-0-0)<br>Total hours: 45 |
|---|---|---|
| **Module 1** | | |
| Historical development of HVAC and HVDC links, comparison, economics of power transmission, technical performance, reliability, limitations, application of dc transmission, description of DC Transmission System, types of DC links and converter station, planning for HVDC transmission. Modern trends in DC transmission. | | |
| **Module 2** | | |
| HVDC transmission analysis of HVDC converters, pulse number, analysis with and without overlap, converter bridge characteristics, converter and HVDC system control, principles of dc link control-starting and stopping of dc link, power control .<br>Introduction to harmonics & filters, generation of harmonics, types of ac filters. | | |
| **Module 3** | | |
| Power flow in AC Systems. Definition of FACTS, power flow control, constraints of maximum transmission line loading. Benefits of FACTS transmission line compensation: uncompensated line, shunt compensation. Series compensation, phase angle control. | | |
| **Module 4** | | |
| Static shunt compensators: SVC and STATCOM. Operation and control of TSC, TSR, TCR and STATCOM, compensator control, comparisons between SVC and STATCOM.<br>Static series compensation: TSSC, SSSC, TCBR, TCPAR. Operation and control applications | | |
| **Module 5** | | |
| Unified Power Flow Controller: circuit arrangement, operation and control of UPFC, basic principle of P and Q control, independent real and reactive power flow control, applications, introduction to interline power flow controller. | | |
| **Reference books** | 1. K. R. Padiyar: HVDC Power transmission System, New age International, 1996.<br>2. N.G Hingorani, L. Gyugyi: Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems, IEEE Press Book, Standard Publishers and Distributors, Delhi, 2001.<br>3. J. Arrillaga: HVDC transmission, IET, 1998.<br>4. E.X. Kimbark: Direct Current Transmission, Vol. I, Wiley Interscience, Newyork, 1971.<br>5. K. R. Padiyar: Power System Dynamics, Stability and Control, 2nd Edition, B.S. Publishers. 1994.<br>6. X.P. Zang, C. Rehtanz and B. Pal: Flexible AC Transmission Systems: Modeling and Control, Birkhauser,2006.<br>7. Y. H. Song and A. T. Johns: Flexible AC Transmission Systems, IET, 1999. | |

| Subject Code EE652 | **Systems and Control Theory** | Credits: 3 (3-0-0) Total hours: 45 |
|---|---|---|
| **Module 1** | | |
| Review of matrices, vector space, group, rings, and fields. | | |
| **Module 2** | | |
| State Space Description: State space representations of systems, state variable modelling of dynamical systems, transfer functions, solution of state equation, transient response, stability of linear systems, Lyapunov methods. | | |
| **Module 3** | | |
| System Analysis: controllability, observability, duality, equivalent systems, system decomposition, diagonal form, controllable and observable canonical forms, state space realizations and minimal realizations. | | |
| **Module 4** | | |
| State Feedback Design: Linear State variable feedback, pole placement for single and multivariable systems, optimal control concept, solution of linear quadratic regulator problem, system decoupling, direct transfer function design procedures. | | |
| **Module 5** | | |
| State Estimation and Servo Control: State observer, reduced order observers, combined observer-controller system, integral control, asymptotic tracking and regulation, robust servo control design. | | |
| **Module 6** | | |
| Nonlinear system Dynamics & Control: Analysis of Modelling equations: state-plane Analysis, Principles of linearization, Describing function methods, Introduction to Nonlinear Control Techniques: Sliding mode control, feedback linearization methods. | | |
| **Reference books** | 1.S.H. Zak: Systems and Control, Oxford Univ. Press, 2003.<br>2. H.K. Khalil: Nonlinear Systems, Prentice Hall, N.J., 2002.<br>3. R. C. Dorf and R. H. Bishop: Modern Control Systems, Prentice Hall, 2001.<br>4. K. Ogata: Modern Control Engineering, Pearson, 2006. | |

| Subject Code EE653 | DSP & FPGA Laboratory | Credits: 2 (0-0-3) Total hours: 45 |
|---|---|---|
| CCS introduction, aliasing, quantization<br>Saw tooth wave generation<br>Single pulse , multiple pulse, sin-triangle and space vector modulation PWM generation<br>Digital filter design<br>FPGA based motor control applications | | |
| **Reference books** | 1. Hamid A. Toliyat: DSP Based Electromechanical Motion Control, 1st Edition, CRC Press, 2004.<br>2. Bin-Wu: High-power Converters and AC Drives, IEEE Press, John Wiley & Sons, 2006<br>3. Wolf: FPGA based system design, Dorling kindersley, 2004. | |

| Subject Code EE654 | Electric Drives Laboratory | Credits: 2 (0-0-3) Total hours: 45 |
|---|---|---|
| Thyristorised drive for 1hp DC motor with closed loop control<br>Single phase & three phase half control and fully controlled bridge rectifier fed separately excited DC motor drive<br>Four quadrant chopper drive for separately excited DC motor drive<br>Speed control of 3 phase wound rotor Induction motor<br>Implementation of single pulse, multiple pulse, sine-triangle and space vector modulation PWM schemes with DSP controller. | | |
| **Reference books** | 1. M.H. Rashid : Power Electronics-circuits, Devices and Applications, 3rd Edition, PHI, 2005.<br>2. Ned Mohan, T.M. Undeland and William P.Robbins: Power Electronics: Converters, Applications, 3rd Edition, John Wiley & Sons, 2009. | |

| **Subject Code**<br><br>**HU650*(Audit Course)** | **Communication Skills and Technical Writing** | Credits: 0 (1-0-2)<br><br>Total hours: 15 Hrs |
|---|---|---|
| **Module 1** | | 12 hours |
| Communication-Definition-Types-Classifications, Presentation Skills-Do's and Don'ts, Reports-Types-Format-Ethics to be followed. | | |
| **Module 2** | | 12 hours |
| Writing Skills: Technical Document-Reports-Instruction Manuals-Project Proposal | | |
| **Module 3** | | 10 hours |
| Writing Exercises: Precis-Summary/Executive Summary/Abstract | | |
| **Module 4** | | 8 hours |
| Preparation of Report- Prefatory Part- Main Part- Terminal Section | | |
| **Reference Books:** | 1. Raman & Sharma, *Communication Skills*, New Delhi: OUP, 2011.<br>2. Mandel, Steve, *Technical Presentation Skills: A Practical Guide for Better Speaking* (Revised Edition), Crisp Learning, 2000.<br>3. Wood, Millett, *The Art of Speaking*, New York: Drake Publishers, 1971.<br>4. Lencioni, Patrick, *The Five Dysfunctions of a Team*: NJ, John Wiley and Sons, 2006. | |

| **Subject Code**<br><br>**EE 655** | **Viva** | **Credits: 2** |
|---|---|---|
| Students will have to attend for a viva-voce in front of all the faculty of the department for the evaluation of the subjects studied in the first year (I and II semesters) with a suitable demonstration. | | |

# Electives

| Subject Code EE801 | Modeling and Simulation of Power Electronic Systems | Credits: 3 (3-0-0) Total hours: 45 |
|---|---|---|
| **Module 1** | | |
| Introduction to ODE solvers, steps of using ODE solvers, Types of mathematical models, Developing a model, Mathematical modeling of simple electrical, Mechanical and electro mechanical systems. | | |
| **Module 2** | | |
| Simulation of power electronic converters: State-space representation, Trapezoidal integration, M and N method. | | |
| **Module 3** | | |
| Modeling: steady state analysis of converters, dynamic analysis of converters, state space average modeling, PWM modeling, modeling of converters operating in continuous and discontinuous conduction mode, converter transfer functions.<br>Simulation of electric drives: Modeling of different PWM Techniques, Modeling and simulation of Induction motor, V/f Control of Induction motor and Vector controlled 3-Ph Induction motor. | | |
| **Module 4** | | |
| Control Techniques in Power Electronics: State space modelling and simulation of linear systems, conventional controllers using small signal models, Fuzzy control, Hysteresis controllers, Output and state feedback switching controllers. Modeling, simulation of switching converters with state space averaging, State Space Averaging Technique and its application in simulation and design of power converters. | | |
| **Reference books** | 1. M. B. Patil, V. Ramnarayanan and V. T. Ranganathan: Simulation of Power Electronic Converters, 1st Edition, Narosa Publishers, 2010.<br>2. Ned Mohan, T.M. Undeland and William P.Robbins: Power Electronics: Converters, Applications, 3rd Edition, John Wiley & Sons, 2009.<br>3. Chee-Mun Ong: Dynamic Simulation of Electric Machinery: Using Matlab/Simulink | |

| Subject Code EE802 | Advanced Power Electronics | Credits: 3 (3-0-0) Total hours: 45 |
|---|---|---|
| **Module 1** | | |
| Non-isolated dc-dc converters: Buck, boost, buck-boost, Cuk, SEPIC, Zeta in DCM and CCM, solated dc-dc converters: Flyback, forward, Cuk, half bridge, push-pull and bridge in DCM and CCM. Single-phase, single-stage converters (SSSSC), power factor correction. Their application in SMPS, UPS, welding and lighting systems. | | |
| **Module 2** | | |
| 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). | | |
| **Module 3** | | |
| Three-phase improved power quality ac-dc converters: VSC , multilevel VSCs, multipulse VSCs, PWM CSC (Current voltage source converters). Multipulse ac-dc converters: Diode and thyristor based converters, power factor correction. | | |
| **Module 4** | | |
| Solid state controllers for motor drives: Vector control and direct torque control of induction, synchronous, permanent magnet sine fed, synchronous reluctance motors, Permanent magnet brushless dc (PMLDC) and switched reluctance motors, LCI (load commutated inverter) fed large rating synchronous motor drives, Energy conservation and power quality improvements in these drives. | | |
| **Reference books** | 1. M.H. Rashid : Power Electronics-circuits, Devices and Applications, 3rd Edition, PHI, 2005.<br>2. Ned Mohan, T.M. Undeland and William P. Robbins: Power Electronics Converters, Applications, 3rd Edition, John Wiley & Sons, 2009.<br>3. Marian K. Kazimierczuk: Pulse-width Modulated DC-DC Power Converters, John Wiley & Sons Ltd., 1st Edition, 2008.<br>4. Robert W. Erickson and DraganMaksimovic: Fundamentals of Power Electronics, Springer, 2nd Edition,2001. | |

| Subject Code EE 803 | **Photovoltaic and its applications** | Credits: 3 (3-0-0) Total hours: 45 |
|---|---|---|
| **Module 1** | | |
| Solar energy: solar insolation vs world energy demand, current energy consumption from different sources, environmental and health effects. Sustainable Energy: production and storage, resources and utilization. | | |
| **Module 2** | | |
| Photovoltaic (PV): Fundamentals of solar cells, types of solar cells, semiconducting materials, band gap theory, absorption of photons, excitation and photoemission of electrons, band engineering, Solar cell properties and design, p-n junction photodiodes, depletion region, electrostatic field across the depletion layer, electron and holes transports, device physics, charge carrier generation, recombination and other losses, I-V characteristics, output power, single junction and triple-junction solar panels, metal-semiconductor hetero junctions and semiconducting materials for solar cells.<br>solar cell applications: pv cell interconnection, module structure and module fabrication, equivalent circuits, load matching, efficiency, fill factor and optimization for maximum power; design of stand-alone PV systems, system sizing, device structures, device construction, installation, measurements, DC to AC conversion, inverters, on-site storage and grid connections. | | |
| **Module 3** | | |
| Optical engineering: Optical design, anti-reflection coatings, beam splitters, surface structures for maximum light absorption, operating temperature Vs. conversion efficiency, types of solar energy concentrators, fresnel lenses and fresnel reflectors, operating solar cells at high incident energy for maximum power output. Cost analysis and environmental issues: Cost analysis and pay back calculations for different types of solar panels and collectors, installation and operating costs; environmental and safety issues, protection systems, performance monitoring. | | |
| **Module 4** | | |
| Thin film solar cells: Single crystal, polycrystalline and amorphous silicon solar cells, cadmium telluride thin-film solar cells, conversion efficiency; current trends in photovoltaic research and applications, nanotechnology applications, quantum dots, solution based processes solar cell production. Photo electrochemical cells for hydrogen production: photo electrochemical electrolysis, photoelectron chemical cells for hydrogen production, solar hydrogen efficiency, hydrogen storage, hydrogen economy. | | |
| **Reference books** | 1. Jenny Nelson: The Physics of Solar Cells, Imperial College Press, 2003<br>2. Stephen J. Fonash: Solar Cell Device Physics, 2nd edition ,Academic Press<br>3. Soteris A. Kalogirou**:** Solar Energy Engineering: Processes and Systems, Academic Press, 2009<br>4. F Lasnier: Photovoltaic Engineering Handbook CRC Press | |

| Subject Code EE804 | Power System Dynamics and Control | Credits: 3 (3-0-0) Total hours: 45 |
|---|---|---|

**Module 1**

**Modelling:** Synchronous machine theory and modelling:- armature and field structure, Parks transformation, machine with multiple pole pairs-mathematical description, d-q transformation, per unit representation, equivalent circuit for d-q axes, steady state analysis- voltage-current and flux linkage, phasor representation, rotor angle – steady state equivalent circuit, Excitation system modelling-excitation systems block diagram - system representation by state equations- State space representation concept, Eigen properties of the state vectors.

**Module 2**

**Stability Analysis:** Small signal stability analysis -small signal stability of a single machine connected to infinite bus system, classical representation of generator, small signal stability of a multi machine connected to infinite bus system. Characteristics of small - signal stability problems.

Transient stability- Concept of transient stability, response to a step change in mechanical power input, Swing equation, multi-machine analysis, factors influencing transient stability, numerical integration method , Euler method, R-K method (4rth order), critical clearing time and angle,methods for improving transient stability.

Voltage stability:- Basic concept, transmission system characteristics, generator characteristics, load characteristics, PV curve, QV curve and PQ curve, characteristics of reactive power compensating devices. Voltage collapse and prevention of voltage collapse.

**Module 3**

**Power System Stabilizer:** Block diagram of PSS, system state matrix including PSS, analysis of stability, small-signal stability improvement methods: delta-omega and delta P-omega stabilizers. Frequency-based stabilizers, Digital Stabilizer, Excitation control design Exciter gain, Phase lead compensation, Stabilizing signal washout stabilizer gain, Stabilizer limits

**Reference books**

1. Kundur: Power System Stability and Control, McGraw-Hill
2. Anderson.P.M and Fouad: Power System Control and Stability”, IEEE Press Power Engineering Series
3. K R Padiyar: Power system Dynamics Stability and Control, B S Publication.
4. Peter W. Sauer and M APai: Power system Dynamics Stability, Pearson Education Asia.
5. Nasser Tleies: Power Systems Modelling and Fault Analysis, Elsevier, 2008.

| **Subject Code EE805** | **Smart Electric Grid** | **Credits: 3 (3-0-0) Total hours: 45** |
|---|---|---|
| **Module 1** | | |
| Introduction to Smart Grid-Smart Grid Functions - Advantages - Indian Smart Grid - Key Challenges for Smart Grid | | |
| **Module 2** | | |
| Smart Grid Architecture -Components and Architecture of Smart Grid Design - Transmission and Distribution Automation - Computational Intelligence Techniques - Distribution Generation Technologies. | | |
| **Module 3** | | |
| Introduction to Renewable Energy Technologies - Micro grids - Storage Technologies - Electric Vehicles andplug - in hybrids - Environmental - Synchro Phasor Measurement Units (PMUs) - Wide Area MeasurementSystems (WAMS) - Control of Smart Power Grid System | | |
| **Module 4** | | |
| Introduction to Factory & Process Automation, PLC, Networking standards. Vertical Integration of Industrial Automation, field bus and Ethernet.Supervisory Control and Data Acquisition (SCADA), introduction to SCADA: grid operation and Control.Distributed Control Systems (**DCS**), difference between SCADA system and DCS, architecture, local control unit, Programming language, communication facilities, operator interface, engineering interfaces. | | |
| **Reference books** | 1. Stuart Borlase: Smart Grids: Infrastructure, Technology, and Solutions, Series: Electric Power and Energy Engineering Published: October 24, 2012 by CRC Press<br>2. Gil Masters: Renewable and Efficient Electric Power System , Wiley-IEEE Press, 2004.<br>3. A.G. Phadke and J.S. Thorp: Synchronized Phasor Measurements and their Applications, Springer, 2008.<br>4. T. Ackermann: Wind Power in Power Systems, 2nd Edition, John Wiley & Sons, 2012<br>5. Michael P. Lukas: Distributed Control Systems, Van NostrandReinfold Company, 1995. | |

| Subject Code EE806 | **Power Quality** | Credits: 3 (3-0-0) Total hours: 45 |
|---|---|---|

**Module 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. Voltage sag, voltage swell, voltage imbalance, voltage fluctuation, over voltages, under voltages, power frequency variations. 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 filters. IEEE and IEC standards of power quality.

**Module 2**

Introduction to APF technology, solutions for mitigation of harmonics, classification of power filters-passive filters, active filters, hybrid filters; active filters applications depending on power quality issues; selection of power filters; categorization of active power filter: converter based categorization, topology based categorization, supply system based categorization, selection considerations of APFS; technical and economic considerations.

**Module 3**

Introduction to active power filter control strategies: shunt active filter basic compensation principle, Clark's transformations, parks transformations, active power filter control strategies, signal conditioning, current control techniques for derivation of gating signals, generation of gating signals to the devices of the APF, hysteresis current control scheme and adaptive hysteresis current control scheme, derivation of compensating signals, compensation in frequency domain, compensation in time domain.

**Module 4**

Control strategies: Instantaneous active and reactive power (p-q) control strategy, Instantaneous active and reactive current ($I_d$-$I_q$) control strategy and perfect harmonic cancellator.

Introduction to Dc link voltage regulation: DC link voltage regulation with PI Controller, Type-1 fuzzy logic controller, Type-2 fuzzy logic controller, and neural networks.

**Reference books**

1) H. Akagi: Instantaneous Power Theory and Applications to Power Conditioning, IEEE Press, 2007.
2) G.T. Heydt: Electric Power Quality, 2nd Edition, West Lafayette, IN, Stars in a Circle Publications, 1994.
3) M.H.J Bollen: Understanding Power Quality Problems: Voltage Sags and Interruptions, NewYork, IEEE Press, 1999.

| Subject Code<br><br>EE 807 | **Soft Computing** | Credits: 3 (3-0-0)<br><br>Total hours: 45 |
|---|---|---|
| **Module 1** | | |
| Introduction to biological and artificial neuron models, operations of artificial neuron, types of neuron activation function, history of artificial neural systems development, Mc-culloch-Pitts neuron model, ANN architectures, neural dynamics (activation and synaptic), neural processing, learning strategies, learning rules. | | |
| **Module 2** | | |
| Classification model, features, and decision regions, discriminant functions, models of Artificial Neural Networks: feed forward network, feedback network, single and multilayer feed forward neural networks- introduction, perceptron models: discrete, continuous and multi-category, training algorithms: discrete and continuous perceptron networks, perceptron convergence theorem, limitations of the single layer perceptron model (XOR Problem), Applications; credit assignment problem, generalized delta rule, Back Propagation Algorithm (BPA), learning difficulties and improvements. | | |
| **Module 3** | | |
| Associative memories: Hebbian learning, general concepts of associative memory (associative matrix, association rules, hamming distance, Bidirectional Associative Memory (BAM) architecture, architecture of Hopfield network: discrete and continuous versions, storage and recall algorithm. Neural network applications: process identification, control, fault diagnosis and load forecasting. | | |
| **Module 4** | | |
| Introduction to classical sets - properties, operations and relations; fuzzy sets, membership, uncertainty, operations, properties, fuzzy relations, cardinalities, membership functions. Fuzzification, membership value assignment, development of rule base and decision making system, fuzzy inference systems: Mamdani max-min and max-product composition scheme, defuzzification to crisp sets, defuzzification methods: COA, BOA, MOM, SOM, and LOM. Design of control rules: trapezoidal MF, triangular MF and Gaussian MF. Rule base fuzzy logic applications: fuzzy logic control and fuzzy classification. Applications of fuzzy systems. | | |
| **Module 5** | | |
| Evolutionary Computation: Different variants, Genetic Algorithm. ; Hybrid Systems: ANFIS, Fuzzy Filtered NN & Neural Fuzzy Systems, GA tuned Fuzzy System. Introduction to Type-2 FLC: The structure of Type-2 FLC, Type-2 fuzzy inference system with different fuzzy MFs (Trapezoidal membership function, Triangular membership function and Gaussian MF). | | |
| **Reference books** | 1. J. M. Zurada: Introduction to artificial neural networks, Jaico publishers, 1997.<br>2. Simon Haykin: Neural Networks A Comprehensive Foundation, Prentice Hall<br>3. J. S. R. Jang, C. T. Sun , E. Mizutani: Neuro-Fuzzy and Soft Computing A Computational Approach to Learning and Machine Intelligence, PHI, 2002.<br>4. Timothy J Ross: Fuzzy Logic with Engineering Applications, TMH, 2007. | |

<table>
<tr><td>Subject Code<br>EE808</td><td colspan="2">DSP Controlled Drives</td><td>Credits: 3 (3-0-0)<br>Total hours: 45</td></tr>
<tr><td colspan="4">Module 1</td></tr>
<tr><td colspan="4">Overview of TMSLF2407 or Advanced DSP controllers: Instruction Set, Interrupts,ADC, Event managers.</td></tr>
<tr><td colspan="4">Module 2</td></tr>
<tr><td colspan="4">Implementation of PWM schemes: Single pulse , Multiple pulse , Sine triangle PWM, Space vector PWM.</td></tr>
<tr><td colspan="4">Module 3</td></tr>
<tr><td colspan="4">Clarke's and park's transformations: Implementation of Clarke's and Park's transformation,</td></tr>
<tr><td colspan="4">Module 4</td></tr>
<tr><td colspan="4">DSP-Based Control of Stepper Motors, BLDC Motors, synchronous motors, Induction Motor</td></tr>
<tr><td>Reference books</td><td colspan="3">1. Hamid A. Toliyat: DSP Based Electromechanical Motion Control, 1st Edition, CRC Press, 2004.<br>2. Bin-Wu: High-power Converters and AC Drives, IEEE Press, John Wiley & Sons, 2006<br>3. R. Krishnan: Electric Motor drives - Modelling, Analysis and Control, PHI India</td></tr>
</table>

| Subject Code EE809 | Digital Control Theory | Credits: 3 (3-0-0) Total hours: 45 |
|---|---|---|
| **Module 1** | | |
| Introduction to Digital Control Systems: Continuous-time Vs Discrete-time Systems, Digital Control Vs Digital Signal Processing (DSP),Signal Discretization, Continuous-time System Analysis, Discrete-time System Analysis, Continuous-time Controller Design, Controller Design for Discrete-time Systems, Controller Implementation. | | |
| **Module 2** | | |
| State Variables Approach to Discrete time Systems: Definition of the State Vector, The MIMO Transfer Function Matrix G(z), State Transformations, Observability and Controllability, Solution of State Equations. | | |
| **Module 3** | | |
| Direct Design of Digital Control Systems Using Transform Techniques: Z-plane Specification of Control System, Design by Discrete Equivalent, Root Locus Design in the z-plane. | | |
| **Module 4** | | |
| Design of Digital Control Systems: A State Space Approach, Control Law Design, State Feedback, Estimator Design, Regulator Design. | | |
| **Module 5** | | |
| The Effect of Quantization, Analysis of Finite Precision Errors, Limit Cycles, Optimal control, Parameter estimation, Adaptive control. | | |
| **Reference books** | 1. K. Zhou, J. Doyle, and K. Glover: Robust and Optimal Control, Prentice-Hall, 1996.<br>2. K. Zhou andJ. C. Doyle: Essentials of Robust Control, Prentice Hall, 1996 | |

| Subject Code EE810 | Optimal Control | Credits: 3 (3-0-0) Total hours: 45 |
|---|---|---|
| **Module 1** | | |
| Calculus of Variations: problems of Lagrange, Mayer and Bolza, Euler-Language equation and transversality conditions, Lagrange multiplier technique | | |
| **Module 2** | | |
| Dynamic programming, Numerical solution techniques, Static and dynamic optimization, Parameter optimization | | |
| **Module 3** | | |
| Pontryagin's principle: theory, application to minimum time, control problems, and terminal control problem | | |
| **Module 4** | | |
| Dynamic programming: Belaman's principle of optimality, multistage decision processes | | |
| **Module 5** | | |
| Linear regulator problem: matrix Riccati equation and its solution, Tracking problem, Computational methods in optimal control, Application of mathematical programming, singular perturbations | | |
| **Reference books** | 1. M. Athans and P.L. Falb: Optimal Control, McGraw Hill, 2007.<br>2. S.P. Sethi and G.L. Thompson: Optimal Control Theory, 2nd edition, Kluwer Academic Publishers, 2000<br>3. D.P. Bertsekas: Dynamic Programming and Optimal Control, Volume I, 3rd edition, Athena Scientific, 2005<br>4. M. Green, D.E. Johnson and D.J. N. Limebeer: Linear Robust Control, Prentice Hall, Digitized Dec 2007 | |