Course Structure & Curriculum

For

M. Tech. Programme

In

Electrical Engineering

With Specialization in

Power Electronics & Drives

(Effective from Session 2017-18)

Department of Electrical Engineering
Motilal Nehru National Institute of Technology Allahabad
Teliarganj, Allahabad-211004, Uttar Pradesh

MOTILAL NEHRU NATIONAL INSTITUTE OF TECHNOLOGY ALLAHABAD

VISION

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

MISSION

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

DEPARTMENT OF ELECTRICAL ENGINEERING

VISION

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

MISSION

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

M.Tech (Electrical Engineering) with specialization in Power Electronics & Drives

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

I Semester

Subject Code	**Subject Name**	**L**	**T**	**P**	**Credits**				**Total Marks**
						TA	MSE	ESE	
EE 21111	Power Electronics	3	1	0	4	20	20	60	**100**
EE 21112	Advanced Electrical Machines	3	1	0	4	20	20	60	**100**
EE 213xx	Elective I	3	1	0	4	20	20	60	**100**
EE 213xx	Elective II	3	1	0	4	20	20	60	**100**
EE 213xx	Elective III	0	0	6	4	50	0	50	**100**

Total Credits = 20

II Semester

Subject Code	**Subject Name**	**L**	**T**	**P**	**Credits**				**Total Marks**
						TA	MSE	ESE	
EE 22111	Electric Drives	3	1	0	4	20	20	60	**100**
EE 22112	Advanced Power Electronics	3	1	0	4	20	20	60	**100**
EE 223xx	Elective IV	3	1	0	4	20	20	60	**100**
EE 223xx	Elective V	3	1	0	4	20	20	60	**100**
EE 223xx	Elective VI	0	0	6	4	50	0	50	**100**

Total Credits = 20

III Semester

Subject Code	**Subject Name**	**Credits**	**Eval (100)**
EE 23652	State of Art Seminar	4	Marks
EE 23602	Thesis	16	Marks

IV Semester

Subject Code	**Subject Name**	**Credits**	**Eval (100)**
EE 24602	Thesis	20	Marks

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

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

Introduction: Power Electronics Systems, Role of Power Electronics in the field of electric power control, Power electronics converters.

Broad overview of Switching Power Devices: Static and dynamic characteristics of switching devices: SCR- BJT- MOSFET- IGBT- GTO.

Controlled Rectifiers: AC to DC Converters, Phase controlled Rectifiers operation on resistive and inductive loads, use of free-wheeling diode, Single -Phase and Three phase controlled and Fully controlled bridge rectifiers, Semi-converters, Dual converters, Effect of source impedance on converter, Line commuted inverters.

Choppers: DC to DC Converters, Principle of operation and control technique of chopper, classification of Choppers, current and voltage waveforms for resistive, inductive and motor loads, Power Transistor and MOSFET based chopper circuits, step up chopper and its application.

Inverters : DC to AC Converters, Single-phase and Three-phase (six-step) inverters, voltage and current waveforms, Bridge Inverter, voltage control & PWM strategies of VSI., Series and parallel inverters, Methods of voltage control, and various techniques of phase width modulation. Comparisons of voltage source and current source inverters and their applications.

Cycloconverters: AC to AC Converters, single-phase and three-phase Step-up and Step down cycloconverter, Full bridge and half

Applications- Static circuit breakers, Static frequency converter, Power factor control, regulation of voltage or current in high power applications, motor controls and power amplifiers.

References:

1. M. H. Rashid, *Power Electronics Circuits, Devices and Applications*, Prentice Hall India, Third Edition, New Delhi, 2004**.**
2. V. Agarwal and K. Kant, *Power Electronics*, BPB Publications, New Delhi 2008.
3. G. K. Dubey, S. R. Doradla, A. Joshi and R. M. K. Sinha, *Thyristorised Power Controllers*, New Age international, Second Edition, New Delhi, 2002.
4. P. C. Sen, *Power Electronics*, Tata McGraw-Hill Education, New Delhi, 2008.
5. P. S. Bimbhra, *Power Electronics*, Khanna Publishers, Fifth Edition, New Delhi, 2014.
6. N. Mohan, *First Course on Power Electronics and Drives*, MNPERE, USA, 2003.
7. N. Mohan, T. M. Undeland and W. P. Robbins, *Power Electronics, Converters, Applications and Design*, Wiley India, Third Edition, 2006.
8. R .S. Ramstrand, *Power Electronics.*
9. M. H. Rashid, *Power Electronics Handbook*, Elsevier, Third Edition, 2011.

Review and analysis: Direct-Current Machines, reference frame theory, Symmetrical Induction Machines, Synchronous Machines, Theory of Brushless dc Machines, winding functions and machine design, machine equations for improving analysis and modelling of machines coupled to power electronic circuits, analysis of unbalanced operation, generalized approach to machine parameters identification, Linearized Machine Equations, Reduced-Order Machine Equations, Switched reluctance motor.

References:

1. Paul C. Krause, Oleg Wasynczuk, Scott D. Sudhoff, and Steven Pekarek, *Analysis of Electric Machinery and Drive Systems*, Wiley-IEEE Press, Third Edition, 2013.
2. T.A. Lipo, and T. M. Jahns, *Introduction to Electric Machines and Drives*, University of Wisconsin, First edition, 2015.
3. D. W. Novotny and T. A. Lipo, *Vector Control and Dynamics of AC Drives*, Clarendon Press, First edition, 1996.
4. Peter Vas., *Sensor less vector and direct torque control*, Oxford 1998.
5. K. Venkataratnam, *Special Electrical Machines*, University Press (India) Pvt. Ltd. 2008.
6. R. Krishnan, *Switched Reluctance Motor Drives*, CRC Press 2001.
7. T. A. Lipo, *Analysis of Synchronous Machines*, 2nd Edition, CRC Press 2012.

Review of classical speed control methods for DC motors, induction motor and synchronous motors, Applications of solid state controller such as choppers, rectifiers, inverters and cyclo-converters in drive system and their performance characteristics, Closed loop control of solid state DC drives. DC motor, stepper motor and variable reluctance motor drives. Variable frequency control of ac drives, Vector control of induction motor and synchronous motors, AC and DC motor drives in transportation system & traction, Case studies.

References:

1. J. M. D. Murphy, *Power electronics control of AC motors*, Perganon Press, New York, 1988.
2. P. C. Sen, *Thyristor DC drives*, Wiley Inter Science Publication, 1981.
3. Vineeta Agarwal, *Fundamentals of Electric drives*, Agarwal Publishing House, First Edition, New Delhi.
4. G. K. Dubey, *Fundamentals of Electric drives*, Narosa Publishing House, Second Edition, New Delhi, 2001.
5. B. K. Bose, *Modern Power Electronics & AC Drives*, Pearson, New Delhi, 2002.
6. V. Subramanayam, *Thyristor control of Electric drives*, Tata McGraw Hill Publication, 1994.
7. S. B. Dewan, *Thyristorized power controller drives*, Wiley Inter Science Publication, New York, 1981.

DC-DC converters modeling and control: Review of basic Switched DC-DC converter circuits: Buck, Boost, Buck-boost, SEPIC, Cuk converters; Analysis of non-ideal switches and circuit elements in DC-DC converters, Parasitic effects on steady state characteristics, efficiency calculation, voltage transfer characteristics with continuous and discontinuous inductor current, Dynamics of converters; State-space averaging, Small signal transfer functions, Voltage and current mode of control.

Isolated and PWM DC-DC converters: Switching power supplies, Unidirectional and bidirectional core excitation, Forward and Flyback Converters, Push-Pull, Full-Bridge and Half-Bridge converters, Steady state and dynamic characteristics, Modeling and Control, Pulse width modulation (PWM) with unipolar and bipolar voltage switching.

DC-AC Inverters: Voltage source and current source inverters, Half-bridge, full-bridge and 3-phase inverter circuits, Fundamental frequency modulation, Sinusoidal pulse-width modulation (SPWM), Space vector modulation (SVM), Compensation for dead time and device voltage drops.

Resonant converters: Hard switched and Soft Switched Converter, Zero-voltage and zero-current switching, Classification of resonant converters, Series and parallel loaded resonant circuits, Continuous and discontinuous mode of operation, Resonant-Switch converters, Zero-current switched (ZCS) DC-DC converter, Zero-voltage switched (ZVS) DC-DC converter.

Modern Rectifiers: Power and harmonics in non-sinusoidal AC systems, Pulse-width modulated rectifiers, Modeling, analysis, and control of low-harmonic rectifiers, Boost, flyback, and other topologies of an ac-dc controlled rectifiers, Switched mode rectifiers, Rectifier/inverter with bi-directional power flow.

Advanced converter topologies and Applications: Multilevel inverter topologies, Z-source inverters, Matrix-converters, Applications: Current controlled voltage source inverters (CCVSI), Active power filters (APF), Uninterrupted power supplies (UPS) etc.

References:

1. N. Mohan, T. M. Undeland and W. P. Robbins, *Power Electronics, Converters, Applications and Design*, Wiley India, Third Edition, 2006.
2. M. H. Rashid, *Power Electronics Handbook*, Elsevier, Third Edition, 2011.
3. V. Ramanarayanan, *Course Material on Switched Mode Power Conversion*, IISc Bangalore, India, Second Edition, 2006.
4. N. Mohan, *First Course on Power Electronics and Drives*, MNPERE, USA, 2003.

5. J. G. Kassakian, M. F. Schlecht and G. C. Verghese, *Principles of Power Electronics*, Addison Wesley, New York, 1991.
6. R. W. Erickson and D. Maksimovic, *Fundamentals of Power Electronics*, Second Edition, Kluwer Academic Publications, 2001.
7. D. W. Hart, *Introduction to Power Electronics*, Prentice Hall International, Upper Saddle River, NJ ,1997.
8. Erickson and Maksimovic, *Fundamentals of Power Electronics*, Second Edition, Springer Science Business 2000.

List of Electives for PE and Drives

List of Subjects in Elective I

1. EE 21331 Power Semiconductor Devices
2. EE 21301 Optimization Techniques
3. EE 21304 Digital Signal Processing
4. EE 21361 Flexible AC Transmission Systems

List of Subjects in Elective II

1. EE 21341 Microprocessor and micro-controller based systems
2. EE 21342 Control Techniques in Power Electronics
3. EE 21314 Virtual Instrumentation
4. EE 21372 Renewable Energy & Grid Integration

List of Subjects in Electives III

1. EE 21351 Power Electronics and Machines Lab.
2. EE 21352 Mini Project

List of Subjects in Elective IV

1. EE 22331 Electric Traction and Vehicles
2. EE 22332 Advanced Control Systems
3. EE 22361 Distribution Automation
4. EE 22363 HVDC Transmission

List of Subjects in Elective V

1. EE 22341 Device Level Circuit & Digital Design
2. EE 22342 Electromagnetic Interference & Compatibility
3. EE 22343 Intelligent Control of Drives
4. EE 22344 Active Power Conditioning

List of Subjects in Electives VI

1. EE 22351 Advanced Power Electronics & Drives Lab.
2. EE 22352 Mini Project

Power switching devices overview: Attributes of an ideal switch, application requirements, circuit symbols; Power handling capability – (SOA); Device selection strategy On-state and switching losses – EMI due to switching - Power diodes - Types, forward and reverse characteristics, switching characteristics and ratings

Current controlled and voltage controlled devices: Review of power electronics devices: Power BJT, Power MOSFET, IGBT, GTO, etc. – Construction, Principle of voltage controlled devices, types, static and switching characteristics, steady state and dynamic models, Negative temperature co-efficient and secondary breakdown, Other emerging devices GTO, MCT, SiC, FCT, RCT, IGCT etc.

Firing and protecting circuits: Necessity of isolation, pulse transformer, optocoupler – Gate drives circuit: SCR, MOSFET, IGBTs and base driving for power BJT. - Over voltage, over current and gate protections; Design of snubber.

Thermal protection : Heat transfer – conduction, convection and radiation; Cooling – liquid cooling, vapour, phase cooling; Guidance for hear sink selection – Thermal resistance and impedance, Electrical analogy of thermal components, heat sink types and design – Mounting types, Packaging and power modules.

References:

1. B.W Williams, *Power Electronics, Devices, Drivers and Applications*, Wiley, New York, 1987.
2. M. H. Rashid, *Power Electronics Circuits, Devices and Applications*, Prentice Hall India, Third Edition, New Delhi, 2004.
3. Vineeta Agarwal and Krishna Kant, *Power Electronics*, BPB Publications, New Delhi 2008.
4. M. D. Singh and K.B Khanchandani, *Power Electronics*, Tata McGraw-Hill, New Delhi 2003.
5. N. Mohan, T. M. Undeland and W. P. Robbins, *Power Electronics, Converters, Applications and Design*, Wiley India, Third Edition, 2006.

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

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

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

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

References:

1. S.S. Rao, *Engineering Optimization: Theory and Practice*. New York: Wiley. 2009.
2. K. Deb, *Multiobjective Optimization using Evolutionary Algorithms.* New York; Wiley. 2002.
3. G.P. Liu, J.B. Yang and J.F. Whidborne, *Multiobjective Optimization and Control*. PHI. 2008.
4. A. D. Belegundu, and T. R. Chandrupatla, *Optimization Concepts and Applications in Engineering,* Pearson Education (Singapore). 2003.
5. R. L. Rardin, *Optimization in Operation Research.* Prentice-Hall. 1999.
6. A. Schirisieer, *Theory of linear and integer programming*, John Wiley and Sons, 1986.
7. D. Leunberger, *Linear and Nonlinear programming*, Add. Wesley, 1984.

EE 21304 Digital Signal Processing **FIRST SEMESTER (E-I)**

DFT- Walsh- Hadamard transforms, discrete convolution and correlation, FFT algorithms, Digital filters-flow graph and Matrix representation, IIR and FIR filter design, Signal processing algorithm, waveform generation, Quadrature signal processing, Signal detection , modulation techniques, frequency translation, over ranging, Issues involved in DSP processor design-speed, cost, accuracy, pipelining, parallelism, quantization error, etc., Key DSP hardware elements - Multiplier, ALU, Shifter, Address Generator, etc., Software development tools-assembler, linker and simulator, Applications using DSP Processor - spectral analysis.

References:

1. V. Oppenheim and R. W. Schafer, *Digital Signal Processing*. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1975.
2. A. Bateman and W. Yates, *Digital signal processing design*, W H Freeman & Co, 1989.
3. A. Antoniou, *Digital filters analysis and design*, McGraw-Hill Science/Engineering/Math; Second Edition, USA, 2000.

EE 21361 Flexible AC Transmission Systems **FIRST SEMESTER (E-I)**

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

References:

1. N. G. Hingorani and L. Gyugyi, *Understanding FACTS*, IEEE Press, New York, 1999.
2. K.R. Padiyar, *FACT's Controllers in Transmission & Distribution,* New Age International, New Delhi, 2007.
3. V. K. Sood, *HVDC and FACTS Controllers: Applications of Static Converters in Power Systems*, Kluwer Academic Publishers, Canada, April 2004.
4. A. Enrique, C.R. F. Esquivel and others, *Modelling and Simulation in Power Networks,* John Wiley.& Sons Ltd., England, 2004.

EE 21341 Microprocessor and Micro-Controller based Systems FIRST SEMESTER (E-II)

Introduction to the general structure of advanced microprocessors and microcontrollers, Discussions on architectures, instruction sets, memory hierarchies, pipelining and RISC principles, interfacing to input and output devices, user interface design, real-time systems, and table-dri;ven software, single chip microcomputers, Interrupt structures, Parallel/serial I/O, Analog I/O, DMA operations, Peripheral controllers, Laboratory based experiments and projects with these devices

References:

1. John B. Peatman, *Design with PIC Microcontrollers*, Pearson Education Asia, 2000.
2. John B. Peatman, *Design with Microcontrollers,* McGraw Hill, USA,1995.
3. Barry B Brey, *INTEL Microprocessors 8086/8088, 80186/80188, 80286, 80386, 80486 Pentium, Pentium Pro Processor, Pentium II, Pentium III, Pentium 4, and Core2 with 64-Bit Extensions Architecture, Programming, and Interfacing*, Eighth Edition, PHI 2009

Introduction: Control of power electronics converters, Switched power converters, Power switching devices, Generic power converters, AC-DC, DC-AC, AC-AC, DC-DC converters control.

State Space modeling of switched converters: State space Models of Electrical Networks, Transient and steady state response of switched converters using state models, Instantaneous solution of load current, Device conduction, Pulse width modulation (PWM), single phase H-bridge and three phase inverter, sinusoidal pulse width modulation (SPWM) analysis of VSI.

Averaging models and Dynamic Analysis: Output and state feedback switching controllers, Averaged models, small-signal models and transfer functions of dc-dc converters, buck, boost, buck-boost converters, Conventional stability analysis, Root-locus method, Frequency response analysis.

Discrete-time Analysis: Discretization of continuous models, Digital control of converter systems, Sampling and ZOH, simulation of Power Electronics converters.

Variable Structure Systems: Variable structure and Sliding Mode control, Linear switched systems, Phase-plane and describing function analysis.

Current Controllers: Hysteresis, Ramp-comparison, Predictive Current controllers, design and analysis, switching frequency dependency on parameters, current control loop design and analysis, closed loop transfer function, bode plots and bandwidth.

Multilevel Converters and Control: Cascaded, Diode-clamp and Flying Capacitor multilevel converters, Multicarrier modulations

Implementation of Power Electronics Controllers: Analog controllers, Computer Control, DSP implementation, ASIC's and embedded controller, FPGA's and Virtual Instrumentation

References:

1. N. Mohan, T. M. Undeland and W. P. Robbins, *Power Electronics, Converters, Applications and Design*, Third Edition, Wiley India, 2006.
2. M. H. Rashid, *Power Electronics Handbook*, Third Edition, Elsevier, 2011.
3. M. P. Kazmierkowski, R. Krishnan and F. Blaabjerg, *Control in Power Electronics (Selected Problems)*, Academic Press, Elsevier Science (USA), 2002.
4. H. S. Ramirez and R. S. Ortigoza, *Control Design Techniques in Power Electronics Devices*, Springer Verlag, London, 2006.
5. V. Ramanarayanan, *Course Material on Switched Mode Power Conversion*, Second Edition, IISc Bangalore, India, 2006.

6. D. O. Neacsu, *Power Switching Converters (Medium and High Power)*, CRC Press, Taylor & Francis Group, LLC, US, 2006.
7. B Wu, *High Power Converter and AC Drives*, IEEE Press, John Wiley & Sons., 2006.
8. T. L. Skvarenina, *The Power Electronics Handbook,* CRC Press, 2002.

EE 21314 Virtual Instrumentation **FIRST SEMESTER (E-II)**

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

References:

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

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

Components required for grid integration, Energy storage components and integration with the grids, Large energy storage technologies (MW), Rechargeable batteries, Supercapacitors, Superconducting magnetic energy storage, Flywheel energy storage, Compressed air energy storage, Grid integration issues and standards. Adequate converter topologies, tariff related to renewable energy interface.

Microgrid structure and operation.

References:

1. M. R. Patel, *Wind and Solar Power Systems*, Tailor & Francis, CRC Press, USA, 2006.
2. M. H. Rashid, *Power Electronics Handbook*, Elsevier, Third Edition, 2011.
3. Bin Wu, Yongqiang Lang, NavidZargari, *Power Conversion and Control of Wind Energy Systems*, Wiley, 2011.
4. Anaya-Lara, N. Jenkins et al, *Wind Energy Generation Modelling and Control*, Wiley, 2009.
5. B. Fox et al, *Wind Power Integration Connection and system operational aspects*, IET, London, 2007.
6. A. Ghosh and G. Ledwich, *Power Quality Enhancement using Custom Power Devices*, Kluwer Academic, USA, 2002.
7. Ali Keyhani, Design of Smart Power Grid Renewable Energy Systems, Second Edition, Wiley-IEEE Press, 2016.

Power Electronics - Hardware

1. To review the static characteristics of different power electronics devices.
2. To obtain the dynamic characteristics of BJT, MOSTET and IGBT.
3. To design and implement single phase and three-phase diode-bridge modules under varying load condition.
4. To design and implement half bridge and full bridge controlled rectifier using single-phase SCR bridge modules with series RL and parallel RC loads.
5. To design and implement controlled bridge rectifier using three-phase SCR bridge modules with RL load.
6. To implement the gate drive for IGBT bridge module as an inverter and study its characteristics.
7. To test the isolated gate drivers for generating pulses to the MOSFET bridge module by varying the pulse width.
8. To d;esign and implement assembled open PCB for 4-channel MOSFET Bridge used as a chopper and as an inverter.
9. To program the given microprocessor (8085) for varying the firing angle of SCR triggering.

Power Electronics – Simulation

10. To simulate half-bridge and full-bridge Diode Bridge rectifier for different load condition using PSPICE software.
11. To simulate half-bridge and full-bridge thyristor bridge rectifier for different load condition using PSPICE software.
12. To simulate the Buck and Boost converter using PSPICE software and obtain the variation of output voltage with duty cycle variation.
13. To simulate the Buck-boost converter using PSPICE software and obtain the variation of output voltage with duty cycle variation.
14. To simulate Bipolar and Unipolar Sinusoidal Pulse Width Modulation (SPWM) using PSPICE software for half-bridge and full-bridge inverter respectively.
15. To design and simulate firing angle control of thyristor controlled reactor (TCR) using Matlab and tabulate the theoretical and simulated values.
16. To simulate the transient and steady state response of current in full-bridge voltage source inverter operating in square wave mode for RL load.
17. To simulate buck and boost converter in voltage and current mode of control.
18. To simulate buck-boost converter in voltage and current mode of control.

19. To design a hysteresis current control Voltage Source Inverter (VSI).

Advanced Electrical Machines and Renewable Energy

20. Study of V-curves of a synchronous Motor
21. To model and simulate the performance of DC shunt and series motor.
22. To model and simulate the performance of a 3-phase induction motor.
23. To model the dynamics of switched reluctance motor using Matlab Simulink.
24. Study of linear magnetic circuit using ANSYS software.
25. To demonstrate the I-V and P-V characteristics of PV module with varying radiation and temperature level. Also demonstrate the I-V and P-V characteristics of series and parallel combination of PV modules.
26. To show the effect of variation in tilt angle on PV module power. Also demonstrate the effect of shading on module output power.
27. To verify the static C_P-λ characteristics of a three bladed wind turbine
28. To simulate a given PV Array and to plot the I-V characteristics using Matlab.

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

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

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

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

References:

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

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Review of Modeling and Analysis of LTI Systems: Modeling of physical Systems. Design specifications and performance indices, Transfer functions reviews, root-locus, frequency response analysis, bode plots, minimum and non-minimum phase systems.

Analysis in state-space: A perspective on state-space design, State variables. State models for electrical circuits, Solution of state equations, Eigen values and eigenvectors, Similarity transformations, diagonalisation, Transformation to canonical forms, Controllability and observability, Lyapunov Stability.

Introduction to Discrete-time Systems: Basic elements of discrete-time control system, z-transform and inverse z-transform, Difference equation and its solution, sampled-data control system, sample and hold, z-transfer function, discretization, state diagram of digital systems, Time delay and modified z-transform, state description of discrete-time systems, state model of sampled continuous-time systems.

Overview of Feedback control design: Proportional, derivative and integral (PID) controller, PID controller tuning rules, design using root-locus and bode plots, Control law design for full state feedback by pole placement, Full order observer system. Observer based state feedback, LQR and dead beat controller

Non linear system: Classification and types of non-linearity, Phenomena peculiar to non-linear systems, Methods of analysis, Linearization based on Taylor's series expansion, Phase trajectory and its construction. Phase-plane analysis of linear and non-linear systems, Existence of limit cycles, Describing function of typical non-linearities, Stability analysis by DF method, Stability analysis by Lyapunov's indirect and direct methods, Lypunov's theorem.

References:

1. Katsuhiko Ogata, *Modern, Control Engineering*, PHI Learning Pvt. Ltd-New Delhi, Fifth Edition, 2010
2. B.C. Kuo, *Automation Control Systems*, Prentice-Hall, Third Edition, 1975.
3. D. Roy Choudhury, *Modern Control Engineering*, Prentice-Hall, 2005.
4. J. Nagrath, M Gopal, *Control System Engineering*, New Age Publishers, New Delhi, Third Edition, 2007.
5. D. G. Schulz, and L. Melsa, *State Functions and Linear Control Systems*, McGraw-Hill, 1967.
6. Stepheni, Shahian, Savant, Hostetler, *Design of feedback control systems*, Oxford University Press, Fourth Edition, 2001.

7. M. Vidyasagar, *Nonlinear System Analysis*, Prentice-Hall, Second Edition, 1993.
8. J.E Gibson., *Nonlinear System*, McGraw-Hill.
9. M. Gopal, *Digital Control and State Variable Methods*, Tata McGraw-Hill Education**,** Fourth Edition, 2012.

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

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

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

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

References

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

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

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

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

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

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

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

References:

1. K. R. Padiyar, *HVDC Power Transmission System*, Wiley Eastern Limited, New Delhi. Second Edition, 1990.
2. Edward Wilson Kimbark, *Direct Current Transmission*, Vol.-I, Wiley Interscience, New York, London, Sydney, 1971
3. Colin Adamson and Hingorani N G, *High Voltage Direct Current Power Transmission*, Garraway Limited, London, 1960.
4. J. Arrillaga, *High Voltage Direct Current Transmission*, Peter Pregrinus, London, 1983.

Introduction: Basic components and circuits, Analog and digital electronics

Device level circuit design: Diode and transistor circuits, Review of basic building blocks of Analog ICs (CS, CG, CD gain stages, Differential stage, mirrors, etc.) Op-amps and Comparators, Reference circuits and voltage regulators, Active filters and oscillators, Temperature and power supply sensitivity, Precision circuits and low noise techniques, Block level IC Design Block diagram of a power management IC, Block level analog circuits in the IC and their design, CMOS Analog Building Blocks.

Digital Design: Design principles for complex digital systems, Iteration, top-down/bottom-up, divide and conquer, and decomposition, Description techniques, including block diagrams, register transfer and hardware description languages, Consideration of transmission line effects on digital systems, Synchronous design, state machine design, Design for testability, PALs, FPGAs, standard cells, timing considerations, fault vectors and fault grading.

References:

1. Paul Horowitz and Winfield Hill, *The Art of Electronics*, Third Edition, Cambridge University Press, 2015.
2. Erickson and Maksimovic, *Fundamentals of Power Electronics*, Second Edition, Springer,2001.
3. Allen and Holberg, *CMOS Analog IC Design*, Oxford University Press, Second Edition Co.,2002.
4. Nripendra N Biswas,*Logic Design Theory*, Prentice Hall of India, 2001.
5. M. Morris Mano, Charles R. Chime, *Logic and Computer Design Fundamentals*, Third Edition, PHI.

EMI & EMC: Introduction: EMC standardization and description, measuring instruments, conducted EMI references, EMI in power electronic equipment: EMI from power semiconductors circuits, Noise suppression in relay systems: AC switching relays, shielded transformers, capacitor filters, EMI generation and reduction at source, influence of layout and control of parasites. EMI filter elements: Capacitors, choke coils, resistors, EMI filter circuits, EMI filter design for insertion loss: Worst case insertion loss, design method for mismatched impedance condition and EMI filters with common mode choke-coils.

Design of Power Converters Components: Design of magnetic components-design of transformer - Design of Inductor and current transformer - Selection of filter capacitors - Selection of ratings for devices - input filter design - Thermal design.

References:

1. Laszlo Tihanyi, *Electromagnetic Compatibility in Power Electronics*, IEEE Press,1995.
2. R. F. Ficchi, *Practical Design for Electromagnetic Compatibility*, Hayden Book Co., 1981.
3. Abraham pressman, keith billings, taylor morey, *Switching Power Supply Design*, McGraw-Hill International, Third Edition, 2009.

Introduction to neural networks: Introduction – biological neurons – Artificial neurons – activation function – learning rules – feed forward networks – supervised learning – perception networks – adaline – madaline – back propagation networks – learning factors – linear separability – Hopfield network – discrete Hopfield networks

Architecture – types: Recurrent auto association memory – bi-directional associative memory – temporal associative memory – Boltzmann machine Hamming networks – self – organizing feature maps – adaptive resonance theory network – Instar – Outsar model – counter propagation network – radial basis function networks

Introduction to Fuzzy sets and Systems: Crisp set – vaguness – uncertainty and imprecision – fuzzy set – fuzzy operation- properties – crisp versus fuzzy relations – fuzzy relation – cardinality operations, properties – fuzzy Cartesian product and composition – non – interactive fuzzy sets – tolerance and equivalence relations – fuzzy ordering relations – fuzzy morphism – composition of fuzzy relations

Fuzzy logic controller: Fuzzy to crisp conversion – Lambda cuts for fuzzy sets and relations – definition methods – structure of fuzzy logic controller – database – rule base – Inference engine

Application and Design: Applications of Neural network and Fuzzy system for single phase fully controlled converter, single phase ac voltage controller, DC Drive and AC Drive, Designing of controllers using Simulation Software Fuzzy Logic Toolbox – Modeling of DC Machines using Simulation Software and Simulink Toolbox

References:

1. L. Fausatt, *Fundamentals of neural networks*, Prentice Hall of India, New Delhi, 1994.
2. T. J. Ross, *Fuzzy Logic with Engineering Applications*, McGraw Hill International Edition, USA, 1997.
3. B. kosko, *Neural Networks and Fuzzy Systems*, Prentice Hall of India, New Delhi, 2011.
4. B. K Bose, *Modern Power Electronics and AC Drives*, Prentice Hall PTR, USA, 2002.

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

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

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

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

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

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

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

UPQC: Structure, Modeling and Control

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

References:

1. A. Ghosh and G. Ledwich, *Power Quality Enhancement using Custom Power Devices*, Kluwer Academic Publisher, Boston, MA, 2002.
2. G. J. Walkileh, *Power Systems Harmonics*, Springer Verlag, New York, 2001.
3. IEEE Standard 519-1992, IEEE recommended practices and requirements for harmonic control in electrical power systems, 1992.
4. R. C Dugan , S. Santoso, M. F. McGranaghan and H. W. Beaty, *Electric Power System Quality*, McGraw-Hill, New York, 2003.
5. M. H. Rashid, *Power Electronics Handbook*, Elsevier, Third Edition, 2011.
6. J. Stones, and A. Collinson, *Power quality*, Power Engg. Journal, vol. 15, no.2, pp. 58-64, April 2001.

7. J. K Phipps, *A Transfer function approach to harmonic filter design*, IEEE Industry Application Magazine, pp. 68-82, March/April, 1997.
8. F. Z. Peng, *Application issues of active power filters*, IEEE Ind. Application Mag., vol.4, no.5, pp.21-30, Sept./Oct. 1998.

<u>List of Experiments</u>

1. To test the performance of Microprocessor controlled reversible DC drive using 1 phase SCR dual converter.
2. To test the performance of Micro-controller based reversible regenerative DC drive using 4-quadrant MOSFET based chopper.
3. To perform slip power recovery using thyristorised Rectifier Bridge converter for wound rotor induction motor.
4. To determine the speed-torque characteristics of single-phase AC motor using thyristorised AC voltage controller with open loop and closed loop control.
5. To control the given 3-phase induction motor using inverter module and SCR AC regulator module with PC interface.
6. To control the given DC motor using Chopper module and SCR Converter module with PC interface.
7. To control the pulse width modulation (PWM) voltage source inverter (VSI) fed 3-phase AC drive with DSP controller.
8. To perform the 4-quadrant operation using IGBT based chopper capable of driving a 0.5-hp dc motor.
9. To perform the control of 3-phase induction motor using IGBT based 3-phase inverter capable of driving a 0.5 hp ac motor.
10. To control the speed of a given three-phase induction motor by V/F (voltage/frequency) control.
11. To perform the Sensor less vector control drive for 3-ph, 1-hp induction motor.
12. To perform the closed loop controlled MOSFET based matrix converter fed induction motor.
13. To control the speed of BLDC motor using pulse width modulation (PWM) method.
14. To control the speed of three-phase induction motor using three-phase AC voltage controller by varying the firing angle of thyristor.
15. To study the Zero Current Source (ZCS) Resonant converter.
16. To test the Microprocessor based 3-phase SCR Half/Full Converter.
17. To perform 3-ph VSI fed PWM inverter AC drive.

Simulation based:

18. To design a flyback converter and study its characteristics.
19. To design a push pull converter and study its characteristics.

20. To design forward converter & study its characteristics.
21. To design a SEPIC converter & study its characteristics.
22. To design a suitable single-phase three level Full bridge (H-bridge) Inverter.
23. To design a suitable single-phase three level Neutral point clamped (Diode clamped) Inverter.
24. To design a three-phase neutral point clamped three-leg line frequency inverter.