M. TECH. – POWER AND ENERGY ENGINEERING

Department of Electrical and Electronics Engineering

The restructuring and deregulation of electric utilities together with recent progress in new and renewable energy technologies introduce unprecedented challenges and wide scope for power and energy systems research and open up new opportunities to young Power Engineers. Conventional Power system is redefined and power electronic components are incorporated along with the existing system. This includes flexible ac transmission, HVDC links embedded in the conventional ac transmission networks etc. Further, use of renewable energy such as solar and wind power, coupled with higher efficiency and conservation, will be the key factors to a sustainable world for future generations.

M. Tech. program in Power and Energy Engineering is intended to explore the above mentioned challenges and also initiate research activities. This program provides necessary theoretical background with a good blend of applied mathematics along with in depth coverage in analysis of power and energy systems. The core courses include sustainable, economic, efficient and reliable energy conversion, generation, transmission, distribution, storage and utilization of electric energy, including application of power electronics in power system operation and control.

CURRICULUM

First Semester

Course Code	Type	Course	L - T -P	Credit
16MA615	FC	Numerical Methods and Optimization	4 - 0 - 0	4
16PR611	FC	Digital Signal Processors	3 - 0 - 1	4
16PR612	FC	Power Electronic Converters	3 - 0 - 0	3
16PR621	SC	Direct Energy Conversion	3 - 1 - 0	4
16PR622	SC	Operation and Control of Power Systems	3 - 0 - 0	3
16PR628	SC	Power and Energy Laboratory I	0 - 0 - 1	1
16HU601	HU	Cultural Education*		P / F
			Credits	**19**

***** Non credit course

Second Semester

Course Code	Type	Course	L - T - P	Credit
16PR613	FC	Basic Energy Dynamics	3 - 0 - 0	3
16PR624	SC	Smart Grid	3 - 1 - 0	4
16PR625	SC	Power Quality	3 - 1 - 0	4
	E	Elective – I	3 - 0 - 0	3
	E	Elective – II	3 - 0 - 0	3
16PR619	FC	Open Laboratory	0 - 0 – 1	1
16PR629	SC	Power and Energy Laboratory II	0 - 0 - 1	1
16EN600	HU	Technical Writing*		P/F
			Credits	**19**

***** Non credit course

Third Semester

Course Code	Type	Course	L - T -P	Credit
	E	Elective – III	3 - 0 - 0	3
	E	Elective – IV – Open Elective*	3 - 0 - 0	3
16PR798	P	Dissertation		6
			Credits	**12**

*****Any of the elective subjects offered in any semester in any department may also be permitted with the concurrence of the department.

Fourth Semester

Course Code	Type	Course	L - T -P	Credit
16PR799	P	Dissertation		16
			Credits	**16**

Total Credits: 66

LIST OF COURSES

Foundation Core

Course Code	Course	L - T - P	Credit
16MA615	Numerical Methods and Optimization	4 - 0 - 0	4
16PR611	Digital Signal Processors	3 - 0 - 1	4
16PR612	Power Electronic Converters	3 - 0 - 0	3
16PR613	Basic Energy Dynamics	3 - 0 - 0	3
16PR619	Open Laboratory	0 - 0 - 1	1

Subject Core

Course Code	Course	L - T - P	Credit
16PR621	Direct Energy Conversion	3 - 1 - 0	4
16PR622	Operation and Control of Power Systems	3 - 0 - 0	3
16PR624	Smart Grid	3 - 1 - 0	4
16PR625	Power Quality	3 -1 - 0	4
16PR628	Power and Energy Laboratory I	0 - 0 – 1	1
16PR629	Power and Energy Laboratory II	0 - 0 - 1	1

Electives

Course Code	Course	L - T -P	Credit
Elective I			
16PR711	Control System Design	3 - 0 - 0	3
16PR712	Energy Systems Modelling and Analysis	3 - 0 - 0	3
16PR713	Advanced Digital Signal Processors and Applications	3 - 0 - 0	3
16PR714	HVDC and FACTS	3 - 0 - 0	3

Elective II			
16PR721	Energy Conservation and Management	3 - 0 - 0	3
16PR722	Restructured Power Systems	3 - 0 - 0	3
16PR723	Power Plant Instrumentation	3 - 0 - 0	3
16PR724	Soft Computing Techniques	3 - 0 - 0	3
Elective III			
16PR731	Wind Energy Conversion Systems	3 - 0 - 0	3
16PR732	Intelligent Communication Systems	3 - 0 - 0	3
16PR733	Power System Stability	3 - 0 - 0	3
16PR734	Energy Storage Technology	3 - 0 - 0	3
Elective IV*			
16PR741	Solar Energy Utilization	3 - 0 - 0	3
16PR742	Modern Power System Protection	3 - 0 - 0	3
16PR743	Bio-Energy Conversion	3 - 0 - 0	3
16PR744	Electric Drives and Control	3 - 0 - 0	3

Project Work

Course Code	Course	L -T -P	Credit
16PR798	Dissertation		6
16PR799	Dissertation		16

16MA615 NUMERICAL METHODS AND OPTIMIZATION 4 - 0 - 0 - 4

Solution of equations and eigen value problems: linear interpolation methods, method of false position, Newton's method, statement of fixed point theorem, fixed point iteration, solution of linear system by Gaussian elimination, Gauss-Jordon methods and iterative methods, inverse of a matrix by Gauss Jordon method, eigen value of a matrix by power method. Initial value problems for ordinary differential equations: single step methods, Taylor series method, Euler and modified Euler methods, fourth order Runge - Kutta method for solving first and second order equations. Multistep methods: Milne's and Adam's predictor and corrector methods. Linear programming: Formulation, graphical and simplex methods, Big-M method, two phase method, dual simplex method, primal dual problems. Unconstrained one dimensional optimization techniques: Necessary and sufficient conditions. Unrestricted search methods: Fibonacci and golden section method, quadratic interpolation methods, cubic interpolation and direct root methods. Unconstrained n- dimensional optimization techniques: Direct search methods, random search, pattern search and Rosen Brooch's hill claiming method, descent methods, steepest descent, conjugate gradient, quasi-Newton method. Constrained optimization techniques: necessary and sufficient conditions, equality and inequality constraints, Kuhn-Tucker conditions, gradient projection method, cutting plane method, penalty function method. Dynamic programming, principle of optimality, recursive equation approach, application to shortest route, cargo-loading, allocation and production schedule problems.

TEXT BOOKS/ REFERENCES:

1. S. S. Rao, "Energy Optimisation Theory and Practice", John Wiley and Sons, 2009
2. Taha H. A., "Operations Research – An Introduction", Eighth Edition, Prentice Hall of India, 2008.
3. Gerald C. F. and Wheatley P. O, "Applied Numerical Analysis", Sixth Edition, Pearson Education Asia, New Delhi, 2002.
4. Balagurusamy. E., "Numerical Methods", Tata McGraw-Hill, New Delhi, 2011.
5. Kandasamy. P., Thilagavathy K. and Gunavathy K., "Numerical Methods", S. Chand Co. Ltd., New Delhi, 2003.
6. Burden R. L. and Faires T. D., "Numerical Analysis", Seventh Edition, Thomson Asia Pvt. Ltd., Singapore, 2002.
7. Fox R. L., "Optimization Methods for Engineering Design", Addition Wesley, 1971.

16PR611 DIGITAL SIGNAL PROCESSORS 3 - 0 – 1- 4

Introduction to micro controllers: Role of micro-controllers and its comparison with microprocessors. Embedded systems and their characteristics, overview of available micro-controllers. PIC16F877A: Architecture, file registers, memory organization, interrupts, electrical characteristics. MPLAB IDE, ADC. AVR/ATMEGA: Introduction, architecture, specifications, ARDIUNO IDE. Signal generation: PWM, SPWM and servo signals. Filtering algorithms. Control Algorithms: P, PI. dSPIC: Introduction, signal analysis-DFT and filtering algorithms.

Practice sessions: LCD display, Interfacing power electronic switches, design of optical encoders, servo motors, voltage and current measurement techniques, wireless communication - Xbee radio modules.

TEXTBOOKS/ REFERENCES:

1. PICmicro™ Mid-Range MCU Family Reference Manual,1997 Microchip Technology Inc., December 1997 /DS33023A.
2. Atmel-8271J-AVR- ATmega-Datasheet_11/2015.
3. PICmicro™ PIC16F87XA Data Sheet 28/40/44-Pin Enhanced Flash Microcontrollers, 2003 Microchip Technology Inc., DS39582B.
4. dsPIC30F Family Reference Manual, 2006 Microchip Technology Inc., DS70046E.
5. Richard C Dorf, "The Engineering Handbook", Second edition, CRC press, 2005.
6. Katsuhiko Ogata, "Discrete-time Control Systems", Second Edition, Prentice Hall International Editions, 1995.

16PR612 POWER ELECTRONIC CONVERTERS 3 - 0 - 0 - 3

Overview of power semiconductor switches: MOSFET, IGBT – characteristics, control and power loss estimation. Overview of single phase and three phase converters, rectifier and inverter modes of operation for RL load. DC-DC converters: buck, boost, buck-boost, Ćuk, forward, fly-back and push-pull converter circuits, half bridge, full bridge - operation, waveforms and design, small signal analysis of DC-DC converters and closed loop control. Resonant DC-DC converters: operating principle, waveforms, switching trajectory and losses. Snubbers: turn-off and turn-on snubbers, drive circuits, inductor and transformer design. Inverters: PWM inverter modulation strategies, unipolar and bipolar switching scheme, sine wave PWM, space vector modulation and predictive current control techniques. Introduction to multi-level inverter (three level inverter): basic topology and waveform, improvement in harmonics. Grid connected inverters: requirement of dead time on line voltages, compensation of dead time.

TEXT BOOKS/ REFERENCES:

1. Ned Mohan, Tore M. Undeland and William P. Robbins, "Power Electronics: Converters, Applications, and Design", Third Edition, John Wiley & Sons, 2003.
2. Muhammad H Rashid, "Power Electronics: Circuits, Devices and Applications", Third Edition, Prentice Hall, 2004.
3. L. Umanand, "Power Electronics: Essentials and Applications" Wiley India, 2009.
4. P. C. Sen, "Modern Power Electronics", S. Chand Limited, 2005.
5. B. W. Williams, "Power Electronics: Devices, Drivers, Applications and Passive Components", Second Edition, Tata McGraw Hill, 1992.

16PR621 **DIRECT ENERGY CONVERSION 3 - 1 - 0 - 4**

Energy scenario: Impact of fossil fuel based systems, global and national energy scenario. Renewable Energy potential: Global and national. Classification of RE technologies: Stand alone, grid connected and hybrid. Direct energy conversion: Energy conversion process-indirect and direct energy conversion. Thermoelectric conversion, photovoltaic conversion, thermionic conversion, magneto-hydrodynamic conversion. Fuel cells: Electrochemical kinetics and transport phenomena. Battery: principles, types, chemical energy conservation equations, polarization effects, specification, selection and design parameters, DoD v/s life cycle curves, charging & discharging methods. Nuclear reactors and nuclear power: fission chain reaction and nuclear reactor fuels. Renewable Energy Technologies: Solar energy, wind energy, Principle of operation, types, configurations - standalone/grid connected, applications. Other Renewable Energy Technologies: Biomass-Gasifiers, Small hydro, wave, tidal, ocean thermal, geothermal. Fuel cells: Principle of operation, types, applications.

TEXT BOOKS/ REFERENCES:

1. Chetan S. Solanki, "Solar Photovoltaics – Fundamentals, Technologies and Applications", Second Edition, PHI Publications, 2011.
2. Leo J. M. J. Blomen and Michael N. Mugerwa, (Editors) "Fuel Cell System", Plenum Press, New York, 1993.
3. George Sutton, "Direct Energy Conversions", McGraw Hill Publications, 1999.
4. Thamas B Johanssson et al, "Renewable Energy Sources for fuel and electricity", Earthscan Publishers, London, 1993.
5. J W Twidell and A D Weir, "Renewable Energy Resources", ELBS, 1998.
6. N K Bansal, M Kleemann and M Mellis, "Renewable Energy Resources and conversion Technology", Tata McGraw Hill, 1990.
7. G N Tiwari, M K Ghosal, "Fundamentals of Renewable Energy Sources", Narosa Publishing House.
8. Kastha D, Banerji S and Bhdra S N, " Wind Electrical Systems", Oxford University Press, New Delhi, 1998.
9. Tony Burton, David Sharpe, Nick Jemkins and Ervin Bossanyi., "Wind Energy Hand Book", John Wiley & Sons, 2004.

16PR622 **OPERATION AND CONTROL OF POWER SYSTEMS** **3 - 0 - 0 - 3**

Introduction: Review of thermal units. The Lambda iteration method, first order gradient method base point and participation factors. Generation with limited supply, take or pay fuel contract, composite generation production cost function, solution of gradient search techniques. Hardlimits and slack variables. hydro-thermal coordination, long range and short range scheduling, hydro-electric plant models, scheduling problems types of scheduling problems. Scheduling energy, short-term hydrothermal scheduling problem, pumped storage hydro plants, pumped storage hydro scheduling λ -γ iteration. Inter change evaluation and power pools, economy interchange evaluation with unit commitments. Types of interchange. Energy banking. State estimation: introduction to advanced topics, detection and identification of bad measurements, estimation of quantities not being measured, network observability and pseudo-measurements. Power system security-system monitoring, contingency analysis, security constrained optimal power flow, factors affecting power system security. Load frequency control, automatic voltage and frequency control, basic concepts of governor mechanism, block diagram representation and mathematical models of speed governing system. State space model of a single area system & two area systems. Voltage control: AGC including excitation system. MVAR control, application of voltage regulator, synchronous condenser, transformer taps, static VAR compensators. SCADA in power systems.

TEXT BOOKS/ REFERENCES:

1. Allen J. Wood and Wollenberg B.F., "Power Generation Operation and Control", Wiley Student Edition, 2008.
2. Nagrath, I.J. and Kothari D.P., "Modern Power System Analysis", Tata McGraw Hill, New Delhi, 2011.
3. A. Monticelli, "Electric Power System State Estimation", Proc. IEEE, Vol. 88, No.2, 2000.
4. Olle I. Elgerd, "Electric Energy and System Theory – An Introduction", Tata McGraw-Hill Publishing Company Limited, New Delhi, 2004.
5. N. V. Ramana, "Power System Operation and Control", Pearson, 2012.
6. Hassan Bevarani, Masayuki Watanabe and Yasunori Mitani, "Power System Monitoring and Control", Wiley-IEEE Press, 2014.
7. Prabha Kundur, "Power System Stability and Control", McGraw-Hill Education, 2011.

16PR628 **POWER AND ENERGY LABORATORY I** **0- 0 - 1 - 1**

This course includes analysis, modeling, design, and testing of electrical power and energy processing systems carried out in a practical laboratory setup. Included are different experiments about power flow studies, fault analysis, protective relaying, FACTS and electronic converters for efficient transmission and utilization of available energy sources.

16PR613 **BASIC ENERGY DYNAMICS** **3 - 0 - 0 - 3**

Thermodynamics**:** Bernoulli's equation, Energy transfer by heat, work and mass, temperature and the zeroth law of thermodynamics. First law and its application, entropy, second law and its application. Irreversibility. Heat Transfer**:** Conduction, radiation, convective heat transfer, two and three-dimensional heat flow. Fluid mechanics**:** Stress-strain relations and viscosity, mass and momentum balance, flow through pipe. Energy conversions in fluid systems. Hydraulic turbines and their performance characteristics. Power plant engineering**:** Capacity, type, selection, comparison, combined cycle power plants. Aerodynamics of wind turbine blades.

TEXT BOOKS/ REFERENCES:

1. S. P. Sukhatme, "A Text Book on Heat Transfer", Orient Longman, 2005.
2. L. Prasuhn, "Fundamentals of Fluid Mechanics, Prentice Hall, 1980.
3. M. W. Zemansky, "Heat and Thermodynamics", Fourth Edition, McGraw Hill, 1968. Page 7 of 20
4. Mott, R. L., "Applied Fluid Mechanics", Sixth Edition, Prentice Hall, NJ, 2006.
5. Herbert B. Callen, "Thermodynamics and an Introduction to Thermo-statistics", John Wiley& Sons, 1985.
6. Morse F T, "Power Plant Engineering", D. Van Nostrand Company Inc,1989
7. Nagpal G. R, "Power Plant Engineering", Khanna Publishers, 41998.
8. Freris L.L. "Wind energy Conversion Systems" – (Prentice Hall1990)
9. J.F.Manwell, J.G. McGowan and A.L. Rogers, "Wind Energy Explained" (John Wiley & Sons Ltd.)

16PR624 SMART GRID 3–1- 0- 4

Review of conventional grid,. EMS/SCADA: Structure and operation. Micro-grids: Need for micro grids, structure of micro grids, AC, DC and hybrid micro grids Operation & Control: Synchronous and asynchronous operation, load flow control, fault studies. Islanded and grid connected modes of operation. Smart Grids: Need for smart power grid systems, basic concepts, smart grid architectural designs, multi-agent system (MAS) technology. Smart grid components: RTU, phasor measurement units (PMU), smart meters, smart sensors & relays, WAMS, AMI, energy storage systems, HEMS. Smart grid communication: – Power line carrier communication, Wireless communication techniques, Network structures (HAN, LAN, NAN, WAN),GIS, google mapping tools. Smart grid operation and control: Load flow, fault & stability analyses, control strategies. Demand side energy management: demand response, role of smart grid technology in demand response, building automation systems, dynamic energy management system. Renewable Energy integration, HEV integration, smart parks.

TEXT BOOKS / REFERENCES:

1. Ali Keyhani, "Design of Smart Power Grid Renewable Energy Systems", John Wiley & Sons, IEEE Press 2011.
2. James Momoh, "Smart Grid - Fundamentals of Design and Analysis", John Wiley & Sons, IEEE Press 2012.
3. Clark W. and Gellings, P.E., "The Smart Grid: Enabling Energy Efficiency and Demand Response", The Fairmont Press, Taylor & Francis 2009.
4. Francis Vanek, Louis Albright and Largus Angenent, "Energy Systems Engineering Evaluation and Implementation", McGraw Hill-2008.
5. Andres Carvello, John Cooper, "The Advanced Smart Grid", ARTECH House, 2011.
6. Prabha Kundur, "Power System Stability and Control", McGraw-Hill Education, 2011.
7. IEEE Power and Energy magazine.

16PR625 POWER QUALITY 3 - 1 – 0 - 4

Review of power quality issues, definitions and standards, causes and effects of power quality issues, measurements. Harmonic studies: Fourier analysis, FFT Analysis, harmonics in HVDC Systems. Improvement techniques: Harmonic and reactive power compensators,conventional compensators, FACTS compensators: Review. Harmonic Filters: Passive filters, tuned filters, design problems, shunt, series and hybrid active filters. Applications: Design problems, estimation of rate/cost reduction due to hybrid filters. Active filter control schemes/algorithms: Instantaneous reactive power theory (IRPT) algorithm, synchronous detection (SD) algorithm, dc Bus voltage algorithm, synchronous reference frame (SRF) algorithm, Icos(Φ) algorithm, AI based control algorithms, analog/digital implementation. Case studies. A review of single-phase and three-phase improved power quality converters and applications. Custom power parks concept: Custom power devices and applications.

TEXT BOOKS/ REFERENCES:

1. J.Arillaga, N.R.Watson and S.Chen, "Power System Quality Assessment", John Wiley & Sons, England, 2000.
2. Math J.Bollen, "Understanding Power Quality Problems-Voltage Sags and Interruptions", John Wiley & Sons, New Jersey, 2000.

3. Enrique Acha and Manuel Madrigal,"Power Systems Harmonics-Computer Modeling and Analysis", John Wiley and Sons Ltd., 2001.
4. George J. Wakileh, "Power Systems Harmonics-Fundamentals, Analysis and Filter Design", Springer-Verlag, New York, 2001.
5. Selected Publications on Power Quality Improvement

16PR619 OPEN LABORATORY 0 - 0 - 1 - 1

The student in consultation with the faculty advisor has to select a topic related to Power and Energy area, write a paper and present it.
Lab training sessions in commonly used ICs and kits (Microcontrollers, FPGA kits etc) to prepare students for project phase.

16PR629 POWER AND ENERGY LABORARTORY II 0- 0 - 1 - 1

This course deals with analysis, modeling, design, and testing of electrical energy processing systems carried out in a practical laboratory setup. Included are experimental setup for efficient utilisation of available energy sources including solar panels. The experiments involve design, modeling, connection and testing of various energy conversion systems.

16EN600 TECHNICAL WRITING P/F

(Non-credit Course)

Technical terms – Definitions – extended definitions – grammar checks – error detection – punctuation – spelling and number rules – tone and style – pre-writing techniques – Online and offline library resources – citing references – plagiarism – Graphical representation – documentation styles – instruction manuals – information brochures – research papers – proposals – reports (dissertation, project reports etc.)

TEXTBOOKS/REFERENCES:

1. H.L. Hirsch, *Essential Communication Strategies for Scientists, Engineers and Technology Professionals,* Second Edition, New York: IEEE press, 2002.
2. P.V. Anderson, *Technical Communication: A Reader-Centered Approach,* Sixth Edition, Cengage Learning India Pvt. Ltd., New Delhi, 2008, (Reprint 2010).
3. W.Jr. Strunk and E.B.White, *The Elements of Style*, New York. Alliyan & Bacon, 1999.

16PR711 **CONTROL SYSTEM DESIGN 3 - 0- 0 - 3**

Control system design by root locus method: lag, lead, lag-lead compensators, control system design by frequency response: lag, lead, lag-lead compensators. PID controller design: Tuning algorithms for PID controllers, optimal PID tuning, anti-reset wind up, derivative kick, modifications to conventional PID controller. Design of control system in state space: Pole placement controller, selection of pole locations for good design, control law design for full state feedback, design of servo systems. Observer design: Reduced order observer, design of regulator systems with observers. Linear Quadratic Regulator, Computer aided designs**.**

TEXT BOOKS/ REFERENCES:

1. M. Gopal, “Modern Control System Theory”, Third Edition, New Age International, 2014.
2. Benjamin C. Kuo, “Digital Control Systems”, Oxford University Press, 2006.
3. G. F. Franklin, J. D. Powell and A. E. Naeini, “Feedback Control of Dynamic Systems”, Pearson, 2009.
4. Graham C. Goodwin, Stefan F. Graebe and Mario E. Salgado, “Control System Design”, PHI Learning, 2003.
5. Norman S. Nise, “Control Systems Engineering”, John Wiley & Sons PTE Ltd, 2013.

16PR712 ENERGY SYSTEMS MODELING AND ANALYSIS 3 - 0 - 0 - 3

Modeling overview: Levels of analysis, steps in model development, examples of models. Quantitative techniques: interpolation-polynomial, Lagrangian. Curve-fitting, regression analysis, solution of transcendental equations. systems simulation, information flow diagram, solution of set of nonlinear algebraic equations, successive substitution, Newton Raphson. Examples of energy systems simulation. Optimisation: objectives/ constraints, problem formulation. Unconstrained problems, necessary & sufficiency conditions. Constrained optimization, Lagrange multipliers, constrained variations, Kuhn-Tucker conditions. Linear programming, simplex tableau, pivoting, sensitivity analysis. Dynamic programming. Search techniques: univariate / multivariate. Case studies of optimisation in energy systems problems. Dealing with uncertainty- probabilistic techniques. Trade-offs between capital & energy using pinch analysis. Energy-economy models: scenario generation, input output model. Numerical solution of differential equations: overview, convergence, accuracy. Transient analysis: application example.

TEXT BOOKS/ REFERENCES:

1. S. S. Rao, “Energy Optimisation: Theory and Practice”, John Wiley and Sons, 2009.
2. S. S. Sastry, “Introductory Methods of Numerical Analysis”, PHI Learning Private Limited, New Delhi, 2012.
3. Y. Jaluria, “Design and Optimization of Thermal Systems”, Taylor & Francis, CRC Press, 2008.
4. W. F. Stoecker, “Design of Thermal Systems”, McGraw Hill, 2011.
5. Yunus A. Cengel, “Thermodynamics: An Engineering Approach”, McGraw Hill, 2008.
6. R. De. Neufville, “Applied Systems Analysis”, McGraw Hill, International Edition, 1990.

16PR713 ADVANCED DIGITAL SIGNAL PROCESSORS AND APPLICATIONS 3-0-0- 3

Pre-requisite: General background of microprocessors and microcontrollers. Overview on Digital signal controllers: C2000 modules, Piccolo based controllers, Delfino based controllers, dsPIC 33F series, MAC units, hardware divide support, floating point signal processing support. dsPIC 30F series: Introduction to 16 bit microcontrollers: dsPIC 30F – CPU, data memory, program Memory, instruction set. Programming using XC16 compiler and C- Interrupt Structure.

Peripherals of dsPIC 30F: I/O Ports, timers, input capture, output compare, motor control PWM, 10 bit A/D converter, UART. Applications using dsPIC30F: Generating SPWM, generating PWM's for power converters, PID based control loops, signal processing based on FIR and IIR filter structures, developing single and multi-point communications with dsPIC and other IC's.

TEXT BOOKS/ REFERENCES:

1. dsPIC30F Family Reference manual, Microchip2008
2. dsPIC30F Programmer's Reference manual, Microchip 2008
3. Chris Nagy, "Embedded System Design using the TI MSP 430 series", First Edition. Newnes, 2003.
4. John G Proakis, G Manolakis, "Digital Signal Processing Principles, Algorithms, Applications", Fourth Edition, Prentice Hall India Private Limited, 2007.
5. www.microchip.com

16PR714 HVDC AND FACTS 3 - 0 - 0 - 3

Steady state reactive power control in transmission systems: requirements in ac power transmission, uncompensated transmission lines, compensated transmission lines, passive shunt compensation, series compensation, compensation by sectioning. FACTS compensators: Shunt compensators: variable z type/passive-TCR, TSC, FC-TCR, TSC-TCR, active/switched converter type. STATCOM. Thyristor controlled phase angle regulator (TCPAR), Thyristor controlled phase shifting transformer (TCPST) and Thyristor controlled voltage regulator (TCVR). Series compensators: variable z type/passive, GCSC, TSSC, TCSC, active/switched converter type- SSSC. Hybrid compensators: UPFC, IPFC, other hybrid compensators. HVDC transmission: comparison of EHVAC and HVDC transmission systems. HVDC links: monopolar, bipolar, homopolar and back to back configurations. Three phase converters: rectifier and inverter modes of operation, 12 pulse converter. DC link power flow control: constant current, constant voltage, constant ignition angle and constant extinction angle control, reactive power requirements. Interconnection between ac and dc systems, converter transformers, design of back to back thyristor converter system.

TEXT BOOKS/ REFERENCES:

1. R. M. Mathur and R. K. Varma, "Thyristor Based FACTS Controllers for Electrical Transmission Systems", Wiley India Pvt. Limited, 2011
2. J. Arrilliga, "Flexible Power Transmission: The HVDC Options", John Wiley and Sons, 2007.
3. K. R. Padiyar, "Facts Controllers in Power Transmission and Distribution", Anshan Publishers, 2009.
4. K. R. Padiyar," HVDC Power Transmission System", New Academic Science, 2011.
5. Narain G. Hingorani and Laszlo Gyugyi, "Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems", Wiley-IEEE Press, 2001.
6. T. J. E. Miller, "Reactive Power Control in Electric Systems", John Wiley and Sons, 1982.
7. E. W. Kimbark, "Direct Current Transmission", Vol 1, Wiley, 1971.

16PR721 ENERGY CONSERVATION AND MANAGEMENT 3 - 0 - 0 - 3

Energy conservation management: general principles of energy management and energy management planning, conducting energy audit, energy audit instruments, energy audit report, monitoring, evaluating and following up energy saving measures/ projects, case study. Energy efficiency analysis, management of heating, ventilating and air-conditioning (HVAC), management of process energy, energy efficiency of turbines, compressors and pumps, specific energy consumption, parameters affecting specific energy consumption, flexi targeting technique. Cogeneration: types and schemes, case study. Management of electrical load and lighting: Management opportunities with electric drives, lighting, electrical load analysis, and peak demand control. economics of power factor improvement: reactive power management, capacitor sizing, location, placement, maintenance, case study. Computer -aided energy management, energy efficiency policy initiatives. Energy economics: Financial evaluation of energy projects, evaluation of proposals, profitability index, life cycle costing approach, investment decision and uncertainty, consideration of income taxes, depreciation and inflation in investment analysis, present worth analysis. Energy conservation in vehicles, energy conservation in buildings.

TEXT BOOKS/ REFERENCES:

1. Barney L. Capehart, Wayne C. Turner and William J. Kennedy, "Guide to Energy Management", Seventh Edition, The Fairmont Press Inc., 2012.
2. Albert Thumann, “Handbook of Energy Audits”, Sixth Edition, The Fairmount Press, 2003.
3. G. G. Rajan, “Optimizing Energy Efficiencies in Industry”, Tata McGraw Hill, 2001
4. Wayne C. Turner, “Energy Management Hand Book”, The Fairmount Press, Inc., 2001.
5. Charles M. Gottschalk, “Industrial Energy Conservation”, John Wiley and Sons, 1996.
6. Craig B. Smith, “Energy Management Principles”, Pergamon Press, 2015.
7. IEEE Recommended “Practice for Energy Management in Industrial and Commercial Facilities”, IEEE std 739 – 1995. (Bronze book).

16PR722 RESTRUCTURED POWER SYSTEMS 3 - 0 - 0 - 3

Background review: review of concepts, marginal cost of generation, least-cost operation, incremental cost of generation, Kuhn-Tucker’s conditions of optimum, inter-utility interchanges. Fundamentals of electricity markets and energy auctions: Introduction to restructuring for power systems, key issues in restructuring, restructuring models, independent system operators (ISOs), supply and demand functions, market equilibrium, types of electricity markets, competitive Gencos in markets, price-based UC, strategic bidding, market power and its mitigation, imperfect Markets. Transmission open access: transmission open access, transmission costing and pricing paradigms, concept of distribution factors in power transmission and their application to pricing, LMPs, transmission capacity, ATC calculations, review of transmission pricing practices – OASIS. Transmission congestion management: Transmission congestion management and transmission rights congestion management models and firm / financial transmission rights. Ancillary services and system security in deregulation: Ancillary services classifications and definitions. System frequency control: Primary regulation and automatic generation control, frequency control practices reactive power ancillary services in electricity markets, country practices. System security in deregulation. Review of electric utility markets in India.

TEXT BOOKS/ REFERENCES:

1. Kankar Bhattacharya, Math H.J. Bollen and Jaap E. Daalder, “Operation of Restructured Power Systems”, Springer, 2012.
2. M. Shahidehpour, H. Yamin and Zuyi Li, “Market Operations in Electric Power Systems: Forecasting, Scheduling, and Risk Management”, John Wiley & Sons, 2003.

3. M. Shahidehpour and M. Alomoush "Restructured Electrical Power Systems – Operation, Trading and Volatility", CRC Press, 2001.

16PR723 POWER PLANT INSTRUMENTATION 3 - 0 - 0 - 3

Overview of power generation, various sources of electrical energy, importance of Instrumentation and control in power generation, piping and instrumentation diagrams. Instrumentation and control in water circuit: water circuit, boiler feed water circulation, measurements in water circuit, controls in water circuit, impurities in water and steam. Instrumentation and control in air-fuel circuit: air-fuel circuit, measurements in air fuel circuit, controls in air-fuel circuit, analytical measurements. Turbine monitoring and control-classification of turbines, instrumentation control points of view, principal parts of turbines, turbine steam inlet system, turbine measurements, turbine control system, lubrication for turbo-alternator, turbo alternator cooling system. Measurements in power plants, Analyzers in power plants, SCADA systems etc.

TEXT BOOKS/ REFERENCES:

1. K. Krishnaswamy, M. PonniBala, "Power Plant Instrumentation", PHI Learning Private limited, New Delhi, 2011.
2. David Lindsley, "Power Plant Control and Instrumentation, The Control of Boilers and HRSG systems", IEE Control Engineering Series 2000.
3. Philip Kiameh, "Power Plant Instrumentation and Controls", McGraw Hill Education, 2014.

16PR724 SOFT COMPUTING TECHNIQUES 3 - 0 - 0 - 3

Introduction and basics: comparison of soft computing methods with conventional artificial intelligence (hard computing), least-square methods for system identification, recursive least square estimator, derivative based optimization, descent methods, Newton's method, conjugate gradient methods. Nonlinear least-squares problems, Gauss Newton method, Levenberg-Marquardt method. Neural networks: different architectures, McCulloch Pitts Model, Hebb network rule single layer and multilayer perceptron networks, ADALINE, MADALINE, learning methods. Learning rules: delta rule and Hebb rule, hybrid learning, back-propagation algorithm, supervised learning, unsupervised learning. Competitive learning: Kohnen's self organizing networks, associative memory neural networks, Hopfield networks. Fuzzy set theory: basic concepts, fuzzy set operators, membership functions. Fuzzy relations, fuzzy measures, rule based system and fuzzy reasoning. Fuzzification and defuzzification methods, fuzzy inference systems, Mamdani, Sugeno, and Tsukamoto, graphical techniques of inference. Fuzzy classification: fuzzy c-means clustering. Fuzzy associative memories, applications. Fuzzy decision making algorithm. Neuro-fuzzy modeling: adaptive neuro-fuzzy inference systems, Neuro-fuzzy controller. Genetic Algorithm: basics of Genetic Algorithms, design issues in Genetic Algorithm, Genetic modeling, hybrid approach, GA based fuzzy model identification. Fuzzy logic controlled Genetic Algorithm, neuro-genetic hybrids & fuzzy-Genetic hybrids. Particle Swarm Optimization: Concept of PSO, algorithm, PSO variations and applications. Ant colony optimization. Case study.

TEXT BOOKS/ REFERENCES:

1. Timothy J. Ross, "Fuzzy Logic with Engineering Applications", Wiley India Private Limited, 2010.
2. S. Rajasekharan and S. A. Vijayalekshmi Pai, "Neural Networks, Fuzzy Logic and Genetic Algorithms", Prentice-Hall India, 2003.
3. James A. Freeman and David M Skapura, "Neural Networks", Pearson Education, 2002.
4. David E. Goldberg, "Genetic Algorithms", Pearson Education, 2003.
5. John Yen and Reza Langari, "Fuzzy Logic, Intelligence, Control, and Information", Pearson Education, Delhi, 2003.
6. Laurene Fausett, "Fundamentals of Neural Networks, Architectures, Algorithms, and Applications", Pearson Education, 2002.
7. J. S. R. Jang, C. T. Sun and E Mizutani, "Neurofuzzy and Soft Computing", Prentice-Hall International, Inc., USA, 1997.
8. Prof. Andries P. Engelbrecht,''Fundamentals of Computational Swarm Intelligence'' Wiley Publications,2005.

16PR731 WIND ENERGY CONVERSION SYSTEMS 3 - 0 - 0 - 3

History of wind turbine development and trends. Wind resource assessment, wind regime modeling, measurement instruments, Weibull parameters, height dependency, wind resources worldwide and in India. Wind energy machine types, classification, parameters. Wind turbine aerodynamics, momentum theories, basic aerodynamics, airfoils and their characteristics. Vertical Axis Wind Turbine (VAWT). Horizontal Axis Wind Turbine (HAWT), blade element theory, Betz limit, wake analysis. HAWT rotor design considerations, number of blades, blade profile, 2/3 blades and teetering, coning, power regulation. Wind turbine loads, aerodynamic loads in steady operation, wind turbulence, and tower shadow. Wind turbine components - braking, yaw system, tower, others. Fixed speed and variable speed systems. Electrical machines for wind energy systems, synchronous and asynchronous generators and power electronics. Integration of wind energy systems to electrical networks, converters, inverters, directly connected. Control systems: requirements, components and strategies. Site selection and turbine spacing, rotor selection, annual energy output (AEO). Small wind turbines: special considerations and designs. Off-shore turbines, testing, noise. Financial considerations: installed costs, payback time, levelized energy cost (LEC).

TEXT BOOKS/ REFERENCES:

1. Joshua Earnest and Tore Wizelius, "Wind Power Plants and Project Development", PHI Learning Pvt. Ltd., New Delhi, 2011.
2. J. F. Manwell, J. G. McGowan and A. L. Rogers, "Wind Energy Explained - Theory, Design and Application", Wiley, 2009.
3. G. M. Pillai, (Conceived & Edited) "Wind Power Development in India", World Institute of Sustainable Energy (WISE), Pune 2006.
4. Freris. L. L., "Wind Energy Conversion Systems", Prentice Hall 1990.

5. Spera D. A., “Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering”, ASME Press, New York, 2009.
6. Johnson G. L., “Wind Energy Systems”, Prentice Hall, 1994 (published by the author online).
7. Voker Quashning, "Understanding Renewable Energy Systems", Earthscan, 2005.

16PR732 INTELLIGENT COMMUNICATION SYSTEMS 3 - 0 - 0 - 3

Introduction to communication systems, block diagram description of analog and digital systems, review of Fourier representations, modulation techniques, analog communication mechanisms, amplitude modulation, frequency modulation, phase modulation, frequency spectrum. Digital modulation schemes, ASK, PSK, FSK, QAM, min-PSK, QPSK, MSK, wireless communication schemes, overview on computer networks, wireless networks .Communication protocols and standards, Ethernet, Power line carrier communication, CAN Bus, I2C, LIN Bus protocol, MODBUS protocol structure; Profibus protocol stack; Profibus communication model, Bluetooth, ZigBee, IEEE 801.11-a,b,g,n, Z-Wave, Cellular networks, WiMAX. Introduction to Smart Grid based communication: Home area network, wide area network, Neighbourhood area network, Wireless Mesh networks, networking issues in smart grid, recent literatures in the area of smart grid communication.

TEXT BOOKS / REFERENCES

1. Bernard Sklar., ‘Digital Communications’, Second Edition, Pearson Education, 2001.
2. John G. Proakis., ‘Digital Communication’, Fourth Edition, McGraw Hill Publication, 2001
3. Theodore S. Rappaport., ‘Wireless Communications’, Second edition, Pearson Education, 2002.
4. Stephen G. Wilson., ‘Digital Modulation and Coding’, First Indian Reprint Pearson Education, 2003
5. Clint Smith. P.E., and Daniel Collins, “3G Wireless Networks”, Second Edition, Tata McGraw Hill, 2007.
6. Vijay. K. Garg, “Wireless Communication and Networking”, Morgan Kaufmann Publishers, http://books.elsevier.com/9780123735805:, 2007.
7. Kaveth Pahlavan. K. and Prashanth Krishnamurthy, "Principles of Wireless Networks", Prentice Hall of India, 2006.
8. William Stallings, "Wireless Communications and networks" Pearson / Prentice Hall of India, 2nd Ed., 2007.
9. Dharma Prakash Agrawal and Qing-An Zeng, “Introduction to Wireless and Mobile Systems”, Second Edition Thomson India Edition, 2007.

16PR733 POWER SYSTEM STABILITY 3 - 0 - 0 - 3

Introduction to power system stability: classical model of single machine connected to infinite bus and a multi machine system. Mathematical modeling of power system elements for stability studies: synchronous machines, excitation system, and power system stabilizer. Small signal analysis. Fundamental concepts of stability of dynamic systems: state space representation, linearization, eigen properties of state matrix, small signal stability of single machine infinite bus (SMIB system, block diagram representation with exciter and AVR, power system stabilizer (PSS), state matrix including PSS, small signal stability of multi machine systems, characteristics of small signal stability problems, small signal stability enhancement. Transient stability analysis: modeling, enhancement methods, high speed excitation systems, discontinuous excitation control, control of HVDC transmission links. Equal area criterion. Sub synchronous resonance. Voltage stability analysis, mechanism of voltage collapse. Determination of shortest distance to instability, important voltage stability indices, prevention of voltage collapse, system design measures, system operating measures.

TEXT BOOKS/ REFERENCES:

1. K. R. Padiyar, "Power System Dynamics", Second Edition, B.S. Publishers, 2008.
2. P. W. Sauer and M. A. Pai, "Power System Dynamics and Stability", Pearson, 2006.
3. P. M. Anderson and A. A. Fouad, "Power System Control and Stability", John Wiley and Sons, 2008.
4. P. Kundur, "Power System Stability and Control", Tata McGraw Hill, 2011.
5. E. W. Kimbark, "Power System Stability", Third Edition Wiley and IEEE Press, 2012.
6. Jan Machowski and Janusz Bialek, "Power System Dynamics: Stability and Control", Second Edition, Wiley, 2008.

16PR734 **ENERGY STORAGE TECHNOLOGY** **3 - 0 - 0 – 3**

Energy storages: Issues of energy accumulation in various forms. Possibility of energy storage. Thermal energy storage, (long and short term - heat storage tanks, ground storage, PCM storage), mechanical energy storage (flywheels). Compressed air energy storages (CAES) - energy storage systems for power plants, industry and air weapons. Hydrogen as an energy carrier, hydrogen production and storage. Fuel cells as energy storage and conversion system. Pumped hydro storage power plant. Electrical energy storages - batteries, capacitors, super capacitors, electromagnetic systems, superconducting magnetic energy storage (SMES). Examples of energy storage systems. Energy management, efficiency of energy storage in different forms. Increase of energy conversion efficiencies by introducing the energy storage.

TEXT BOOKS/ REFERENCES:

1. Aiping Yu, Victor Chabot and Jiujun Zhang, "Electromechanical Energy Storage and Conversion", CRC Press, Taylor & Francis Group, (ISBN - 978-1-4398-6989-5), 2013.
2. A.G.Ter-Gazarian, "Energy Storage for Power Systems", Second Edition, The Institution of Engineering and Technology (IET) Publication, UK, (ISBN - 978-1-84919-219-4), 2011.
3. Robert A. Huggins, "Energy Storage", Springer Science (ISBN - 978 -1-4419-1023-3), 2010.
4. A. R. Pendse, "Energy Storage Science and Technology", SBS Publishers & Distributors Pvt. Ltd., New Delhi, (ISBN - 13:9789380090122), 2011
5. Frank S. Barnes and Jonah G. Levine, "Large Energy Storage Systems Handbook", Taylor and Francis Group (ISBN - 978-1-4200-8600-3), 2011.
6. Electric Power Research Institute (USA), "Electricity Energy Storage Technology Options: A White Paper Primer on Applications, Costs, and Benefits" (1020676), December 2010.
7. International Electro-technical Commission (IEC), Switzerland, "White Paper on Electrical Energy Storage", December 2011.
8. Paul Denholm, Erik Ela, Brendan Kirby and Michael Milligan, "The Role of Energy Storage with Renewable Electricity Generation", National Renewable Energy Laboratory (NREL) -

A National Laboratory of the U.S. Department of Energy - Technical Report NREL/ TP6A2-47187, January 2010.

16PR741 SOLAR ENERGY UTILIZATION 3 - 0 - 0 -3

Solar energy fundamentals: solar radiation, solar cell & its characteristics, solar PV modules: series & parallel connection. Solar energy collectors, concentrator PV cells and heliostat systems. Solar photovoltaic applications: types of systems, system design, balance of solar PV systems. Maximum power point tracking, solar PV inverter & converter design, energy storage options for solar PV systems with controllers, battery & fuel cell, design of off-grid PV systems, design of grid-connected PV systems, hybrid system design, life cycle cost analysis, installation & maintenance of SPV plants with standards. Solar street lighting & water pumping applications: design considerations & system design. Solar thermal applications: space/ air heating & cooling, active & passive heating and cooling of buildings, solar cooking, solar distillation, solar dryers for process plants, solar pond, solar collector and thermal storage: steady state and dynamic analysis, modeling of solar thermal systems and simulations in process design. Design of active systems by f-chart and utilizability methods. Thermoelectric - photovoltaic integrated modules for heating and electricity applications.

TEXT BOOKS/ REFERENCES:

1. Chetan Singh Solanki, “Solar Photovoltaics: Fundamentals, Technologies and Applications”, Second Edition, Prentice Hall of India, 2011.
2. S. P. Sukhatme, “Solar Energy - Principles of Thermal Collection and Storage”, Third Edition, Tata McGraw-Hill, New Delhi, 2008.
3. D. Y. Goswami, F. Kreith and J. F. Kreider, “Principles of Solar Engineering”, Taylor and Francis, Philadelphia, 2000
4. M. S. Sodha, N. K. Bansal, P. K. Bansal, A. Kumar and M. A. S. Malik, “Solar Passive Building: Science and Design”, Pergamon Press, New York, 1986.
5. M. A. S. Malik, G. N. Tiwari, A. Kumar and M. S. Sodha, “Solar Distillation”, Pergamon Press, New York, 1982.

16PR742 MODERN POWER SYSTEM PROTECTION 3 - 0 - 0 - 3

Introduction to electromagnetic relays: thermal relays, static relays, microprocessor based relays. Static relays: merits and demerits, comparators, amplitude and phase comparators, duality between amplitude and phase comparators. Over-current protection: time current characteristic, special characteristic, different types of static over current relays, static over voltage and under voltage relays, static directional relays. Distance protection scheme: standard 3 zone protection, types of static distance relays, impedance, reactance, mho, quadrilateral, elliptical, effect of arc resistance and power surges in the performance of distance relays, pilot relaying scheme, wire pilot protection, carrier current protection. Microprocessor based protective relays: over current relay, impedance relay, directional relay, reactance relay. Basic protection scheme using microcomputers. Computer application to protective relays: digital simulation of power system disturbance, digital simulation of distance relay during transients, on line and off line application of computers to protection. Reliability and protection: reliability, redundancy, continuous supervision and self-diagnosis, automatic testing, test methods for static relays, maintenance and field testing of relays.

TEXT BOOKS/ REFERENCES:

1. T. S. Madhava Rao, "Power System Protection: Static Relays", Tata McGraw Hill, 2004.
2. Badari Ram and D. N. Viswakarma, "Power System Protection and Switchgear", Tata McGraw Hill, 2011.
3. Bhuvanesh A. Oza, "Power System Protection and Switchgear", Tata McGraw Hill, 2010.
4. C. R. Mason, "The Art and Science of Protective Relays", Wiley Eastern, 1992.
5. M. V. Deshpande, "Switchgear Protection", Tata McGraw Hill, 2002.
6. Mac Donald, "Power System Protection. Volume- I, II & III Edited by the Electricity Council", Tata McGraw Hill, 1993.

16PR743 BIO - ENERGY CONVERSION 3 - 0 - 0 - 3

Bio-energy: bio-mass gasification and biogas systems, types of biomass gasification, pyrolysis. Anaerobic digestion of wastes, high performance bio-gas systems, cleaning of bio-gas, use of bio- mass for electricity production, bio-gas compression and storage. Micro algae for oil production, straight vegetable oil (SVO) in engines, organic wastes to electricity, waste to energy (WTE) systems for municipal solid wastes (MSW), vegetable, fish and meat processing residues. Direct combustion, bio-energy for off-grid electrification, hybrid renewable energy systems.

TEXT BOOKS/ REFERENCES:

1. Prabir Basu, "Biomass Gasification and Pyrolysis", Elsevier Inc., 2010.
2. Sunggyu Lee and Y. T. Shah, "Biofuels and Bioenergy: Processes and Technologies", CRC Press, Taylor & Francis Group, 2013.
3. Erik Dahlquist, "Biomass as Energy Source Resources, Systems and Applications", CRC Press, Taylor & Francis Group, UK, 2013.

16PR744 ELECTRICAL DRIVES AND CONTROL 3 - 0 - 0 - 3

Fundamentals of electric drives, dynamics of electric drives, multi quadrant operation, closed loop control of drives. DC motors: methods of speed control, dual converter fed DC motor drives, chopper fed drives, single, two and four quadrant chopper drives. Speed control of 3 Phase induction motors, stator voltage control, principle, operation and applications. Slip power recovery scheme, principle, static Kramer's drive, static Scherbius drive, applications. V/f control, constant torque and constant power control. Speed control of synchronous motors, principles of synchronous motor control, self-controlled synchronous motor with electronic commutation, self-controlled synchronous motor drive using load commutated thyristor inverter. Primitive machine: unified approach to the analysis of electrical machine, basic two pole model of rotating machines, Kron's primitive machine, voltage, power and torque equation, linear transformation from 3 phase to 2 phase and from rotating axes to stationary axes, invariance of power. Principle of vector Control: vector controlled induction motor drive, basic principle, direct rotor flux oriented vector control, estimation of rotor flux and torque, implementation with current source and voltage source inverters. Stator flux oriented vector control, indirect rotor flux oriented vector control scheme, implementation, tuning (include lab practice). Vector control strategies for synchronous motor. Introduction to sensor-less control, basic principle of direct torque control. PLC based control.

TEXT BOOKS/ REFERENCES:

1. R. Krishnan, "Electric Drives: Modeling, Analysis and Control", PHI, 2007.
2. Vedam Subramaniam, "Electric Drives: Concepts and Applications", Tata McGraw Hill, 2011.
3. Bose B. K, "Modern Power Electronics and AC Drives", Pearson Education Asia, 2002.
4. N. K. De and P. K. Sen, "Electric Drives", PHI, New Delhi 2001.
5. M. D. Singh and K. B. Khanchandani, "Power Electronics", Tata McGraw Hill, 2008.