DEPARTMENT OF ELECTRICAL ENGINEERING, MANIPAL UNIVERSITY JAIPUR

M. Tech. in POWER ELECTRONICS & DRIVES (PED)

Year	FIRST SEMESTER						SECOND SEMESTER					
	Sub. Code	Subject Name	L	T	P	C	Sub. Code	Subject Name	L	T	P	C
I	MA6103	Computational Methods & its Applications	3	1	0	4	EE6201	Advanced Power Electronic Converters	3	1	0	4
	EE6170	Research Methodology	3	0	0	4	EE6202	Power Semiconductor Controlled Drives	3	1	0	4
	EE6101	Control System Design	3	1	0	4	EE6203	Digital control of Power Electronics and Drive System	3	1	0	4
	EE6102	Modelling of Power Electronics Converter	3	1	0	4	EE62**	Program Elective- I	3	1	0	4
	EE6103	Modelling and analysis of Electrical Machines	3	1	0	4	EE624*	Program Elective- II	3	1	0	4
	EE6104	Electric Vehicle Technology	3	1	0	4	EE628*	Open Elective-I	3	0	0	3
	EE6130	Electric Drive I Lab	0	0	4	2	EE6230	Electric Drive II Lab	0	0	4	2
			18	**5**	**4**	**25**			**18**	**5**	**4**	**25**
	Total Contact Hours (L + T + P)		27				**Total Contact Hours (L + T + P) + OE**		24 + 3 = 27			
	THIRD AND FOURTH SEMESTER											
II	EE7070	Dissertation							0	0	0	25
									0	**0**	**0**	**25**
	Total Contact Hours (L + T + P) + OE								**0**			

Program Elective

1. EE6240: Digital Signal Processing & Applications
2. EE6241: Digital System Design Using FPGA
3. EE6242: Soft Computing Techniques
4. EE6243: Power Quality Issues & Mitigation
5. EE6244: Distributed Energy Resources
6. EE6245: Energy Storage Devices
7. EE6246: Lighting Controls: Technology & Applications
8. EE6247: Microgrid

Open Elective

1. EE6280: Photovoltaic Systems
2. EE6281: Intelligent Control Systems

MANIPAL UNIVERSITY • JAIPUR

School of Electrical, Electronics & Communication Engineering
Department of Electrical Engineering

M. Tech (Power Electronics & Drives) Syllabus

(Applicable for the students admitted in Academic Year 2019-20 & onwards)

FIRST SEMESTER

MA6103: COMPUTATIONAL METHODS & APPLICATIONS [3 1 0 4]

Numerical Methods: Linear Algebraic equations- LU decomposition and matrix inversion, special matrices, eigen values, characteristic vectors, Cayley-Hamilton theorem– minimal polynomial, Sylvester's interpolation method, various canonical form, algebra of polynomial matrices, Numerical differentiation & integration- Newton cotes integration, numerical differentiation applied to engineering problems. Gauss-Seidel Method and Newton-Raphson Method for solution of simultaneous linear and nonlinear equations applied to engineering problems. Numerical Solution of Ordinary differential equations- Euler's Methods and Runge-Kutta (RK-2 & Rk-4) Methods, boundary value & eigen value problems. Numerical solutions of Partial Differential Equations- Finite difference methods for elliptic, parabolic and hyperbolic equations applied to engineering problems.

References:

1. C. C. Steven and R. P. Canale, *Numeric Methods for Engineers*, TMH, 2006.
2. S. S. Sastry, *Numerical Analysis for Engineers*, TMH, 2002.
3. M. T. Nair, A. Singh, *Linear Algebra*, PHI, 2002.
4. F. R. Gantmocher, *The Theory of Matrices*, Chelsea Publishing, 1960

EE6170: RESEARCH METHODOLOGIES AND TECHNICAL COMMUNICATION [3 0 0 3]

EE6101: CONTROL SYSTEM DESIGN [3 1 0 4]

Control system performance objectives, Design of cascade & feedback compensation, Scalar and multivariable control systems, Industrial PID controllers, state space systems and PID control, PID tuning, Pole placement techniques for design of controllers and observers, Kalman filter, Robust control, H techniques; Non-linear control system design: Linearization, compensation and design of non-linear systems, design of non-linear control system using phase plane analysis, Lyapunov stability; optimal control theory and applications; Adaptive Control ; Self tuning control; Model reference adaptive control; practical aspects: Control system design examples; MATLAB & SIMULINK for Control system Design.

References:

1. K. Ogata, *Modern Control Engineering* (5e), PHI, 2010.
2. S. M. Shinners, *Advanced Modern Control System Theory and Design*, John Wiley & Sons, 1998.
3. M. A. Johnson and M. M. Moradi, *PID Control: New Identification and Design Methods*, Springer 2005.
4. V. I. George and C. P. Kurian, *Digital Control Systems* (1e), Cengage Learning, 2012.
5. N. S. Nise, *Control Systems Engineering* (5e), John Wiley & Sons, 2010.

EE6102: MODELLING OF POWER ELECTRONIC SYSTEMS [3 1 0 4]

Computer Simulation of Power Electronic Converters and Systems: Challenges in computer simulation, simulation process, Types of analysis, mechanics of simulation, circuit-oriented simulators, equation solvers, General overview and understanding of SPICE/PSPICE and MATLAB SIMULINK software. Modeling of Systems: Input-Output relations, differential equations and linearization, state space representation, transfer function representation, Modelling of Power Electronic Converters: Modelling of semiconductor devices, Switch realization– single quadrant and two quadrant switches, switching losses, Review of DC-DC converters: Steady-state analysis of converter in continuous and discontinuous modes (CCM & DCM), and estimation of converter efficiency, Development of circuit model for simulating dynamic operating conditions in CCM & DCM, Feedback control for converters, Controller design techniques, Bode diagram method, PID controller design, root locus method, state space method. Tracker, controller design, controlling voltage, controlling current. Introduction to digital control of switched-mode power converters. MATLAB Simulation for different emerging applications.

References:

1. M. H. Rashid, *Power Electronics Circuit Devices and Applications*, Prentice Hall of India 2014.
2. N. Mohan et. al., *Power Electronics, Converters, Applications & Design*, Wiley, 2014

3. R. W. Erickson and D. Maksimovic, *Fundamentals of Power Electronics*, Springer, 2010.
4. The Mathworks Inc., *MATLAB the Language of Technical Computing*, version 6.5.

EE6103: MODELLING AND ANALYSIS OF ELECTRICAL MACHINES [3 1 0 4]

Basics of magnetic circuits, Analysis of magnetic circuits with air gap and permanent magnets, Analysis of singly excited electromechanical system with linear magnetics, nonlinear magnetics using energy and co-energy principles. Inductances of distributed windings - salient pole, cylindrical rotor, Analysis of the doubly excited two-phase rotational system, Reference frames power invariance and non-power invariance, Derivation of dc machine systems from the generalized machine, Analysis of induction machine - synchronous reference frame - with currents as variables - with rotor flux as variables. Basis for vector control - small signal modelling of induction machine, Analysis of the alternator - synchronous reference frame, Derivation of salient and cylindrical rotor machine phasor diagrams. Three phase short circuit of alternator and various time constants. Lab (Simulation) Exercises on start-up transient in DC motor, transients in Induction motor, small signal model of DC and Induction machine, inverter fed Induction motor, slip test of salient pole alternator.

References:

1. Fitzgerald and Kingsley, *Electric Machinery* (7e), MGH, 2013
2. Hancock, *Matrix Analysis of Electric Machinery* (2e) Pergamon Press, 2016
3. O. Wasynczuk, S. D. Sudhoff and P. C. Krause, *Analysis of Electric Machinery and Drive Systems* (2e), Wiley, 2010.

EE6104: ELECTRIC VEHICLE TECHNOLOGY [3 1 0 4]

Introduction to Electric Vehicles - History, social and environmental importance, Impact of modern drive-trains; Conventional Vehicles: Basics of vehicle performance, vehicle power source characterization, Electric Drive-trains - Basic concepts, power flow control, topologies; Electric Propulsion unit: Introduction, Configuration and control of DC Motor drives, Induction Motor drives, Permanent Magnet Motor drives, Switch Reluctance Motor drives, Energy Storage - Introduction, Charging technologies, Battery based energy storage, Fuel Cell based energy storage, Super Capacitor based energy storage and Flywheel based energy storage and analysis, Sizing the drive system - Sizing the propulsion motor, power electronics, energy storage technology, Communications, Supporting subsystems - Energy Management Strategies, Battery management systems, Fleet management systems, EV standards, Case Studies - Design of a Battery Electric Vehicle (BEV)

References:

1. M. Ehsani, Y. Gao, S. E. Gay, and A. Emadi, Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, CRC Press, 2004.
2. C. Mi, M. A. Masrur and D. W. Gao, Hybrid Electric Vehicles, Wiley 2011
3. S. Rajkaruna, F. Shahnia, *Plug in Electric Vehicles in Smart Grids*, Springer, 2015
4. S. Dhameja, *Electric Vehicle Battery Systems*, Newnes, 2001.
5. R. Krishnan, *Permanent Magnet Synchronous and Brushless DC Motor Drives*, CRC Press, 2009
6. R. N. Jazar, *Vehicle dynamics: theory and application*, Springer, 2017

EE6130: ELECTRIC DRIVE I LAB [0 0 2 4]

Implement the Single Phase Converter Controlled DC motor Drives, Study the operation of Buck, Boost DC – DC Converter, DC to DC converter controlled DC motor drives. Three Phase AC to DC Converter controlled DC Motor Drives, Concept of DC to DC converter for fast charging system, Open & Closed Loop Speed Control of PMDC Drives using Micro Controller, Speed control of BLDC Motor Drive, Speed controller of BLDC Motor Drive for Electric Vehicle Application.

References:

1. M. H. Rashid, *SPICE for Power Electronics & Electric Power* (3e), CRC Press,2012.
2. R. W. Erickson, D. Maksimovic, *Fundamentals of Power Electronics* (2e), Springer,2005.
3. R. Krishnan, *Permanent Magnet Synchronous and Brushless DC Motor Drives*, CRC Press, 2009.
4. S. Dhameja, *Electric Vehicle Battery Systems* (1e), Newnes, 2001.

SECOND SEMESTER

EE6201: ADVANCE POWER ELECTRONICS CONVERTERS [3 1 0 4]

Advance Power electronics Converters for Wireless Power Transfer: Basic operating principle of wireless power transfer, wireless power transfer methods: capacitive wireless transfer, magnetic gear wireless transfer, resonant inductive power transfer (IPT), wireless power transfer for vehicular applications: static wireless electrical vehicle charging, various topologies in static wireless charging, design considerations, derivation of electrical parameters and efficiency, parameter designing of 500 W static wireless charging, mathematical modelling of Series-Series(SS) compensated IPT, closed loop control design of SS compensated IPT, dynamic wireless electrical vehicle charging. Drone Charging using IPT, IPT in Biomedical applications. Power Electronics in Vehicle to Grid Integration (V2G): Introduction, Bidirectional converters for V2G systems, bidirectional AC-DC converter, full bridge topology, eight switch topology, three level topology, single stage topology, matrix converter based topology, comparision of various bidirectional ac-dc converters, bidirectional dc-dc converters (bdcs), isolated topologies, non-isolated topologies, resonant topologies, comparison of bdcs.

References:

1. C. T. Rim and C. Mi, *Wireless power transfer for electric vehicles and mobile devices*, John Wiley & Sons, 2017.
2. K. Aditya, *Design and implementation of an inductive power transfer system for wireless charging of future electric transportation* (Doctoral dissertation).
3. Prasanna and K. Durga, *Design and analysis of magnetic resonance based wireless charging system for electric vehicle* (Doctoral dissertation).
4. A. Sharma, and S. Sharma, *Review of power electronics in vehicle-to-grid systems*, Journal of Energy Storage, Vol. 21, pp 337-361, 2019.
5. J. M. Arteaga et al., *Dynamic Capabilities of Multi-MHz Inductive Power Transfer Systems Demonstrated with Battery-less Drones*, IEEE Transactions on Power Electronics, Vol. 34, Issue 6, pp 5093-5104, 2018.

EE6202: POWER SEMICONDUCTOR CONTROLLED DRIVES [3 1 0 4]

Motor load dynamics, starting, braking & speed control of dc and ac motors. DC drives: converter and chopper control. AC Drives: Operation of induction and synchronous motors from voltage and current inverters, slip power recovery, pump drives using ac line controller and self-controlled synchronous motor drives. closed loop control of solid state DC drives, Scalar and vector control of induction motor, Direct torque and flux control of induction motor, Self-controlled synchronous motor drive, Vector control of synchronous motor, Switched reluctance motor drive, Brushless DC motor drive, Permanent magnet drives, Industrial drives.

References:

1. G. K. Dubey, "Fundamentals of Electric Drive" Narosa Publishing House 1995.
2. G. K. Dubey, "Power Semiconductor Controlled Drives" Prentice Hall Inc., A division of Simon and Schester England cliffs, New Jersey 2002.
3. N. K. De and P. K. Sen, "Electric Drive," Prentice Hall of India, 1999.
4. B. K. Bose, "Modern Power Electronics and AC Drives" Prentice Hall of India (PHI), 2012.

EE6203: DIGITAL CONTROL OF POWER ELECTRONICS AND DRIVE SYSTEM [3 1 0 4]

Review of Digital signal processors/Microcontrollers, Introduction to DSP/micro-controllers and their application to power electronic conversion, Theory of sampling, z transformations, sampling techniques in power electronic converters, Signal analysis, Digital PWM generation schemes, Realization of different PWM's using DSP's, Algorithms and programming of digital controllers, Implementation aspects and application of modern digital controllers. Control of DC-DC Converters, Control of Inverters, Control of power factor correction, Control of DC Machine, Control of AC Machine, Control of PMBLDC, PMSM and SRM.

References:

1. S. W. Smith, *The Scientist & Engineer's Guide to Digital Signal Processing*, California Technical Pub, 1998.
2. M. S. Santina, A. R. Stubberud and G. H. Hostetter, *Digital Control System Design* (2e), Oxford University Press, 1994.
3. H. A. Toliyat and S. G. Campbell, *DSP based electromechanical motion control* (1e), CRC Press, 2003.
4. A. I. Pressman, Keith Billings and Taylor Morey, *Switching Power supply design* (3e), MGH, 2009.
5. R. W. Erickson and D. Maksimovic, *Fundamentals of Power Electronics*, Springer, 2010.

EE6230: ELECTRIC DRIVE II LAB [0 0 2 4]

Speed Control of Induction Machine Drives using Three Phase Cycloconverter, Open & Closed Loop Speed Control of AC Induction Motor Drives using Micro Controller, Vector control of Induction Motor Drive for different Industrial Operations, Switched Reluctance Electric Motor Drive. Synchronous

Motor Drives, Speed controller of Variable Frequency Induction motor drives for Electric Vehicle Application.

References:

1. Seref Soylu, *Electric Vehicles –Modelling and Simulations*, InTech, 2011.
2. P. Krause, O. Wasynczuk, S. Sudhoff and S. Pekarek, *Analysis of Electric Machinery and Drive Systems* (3e), IEEE Press, 2013.
3. K. T. Chau, *Electric vehicle Machines and drives, Design, analysis and application* (1e), John Wiley & Sons, 2015.

THIRD AND FOURTH SEMESTER

EE7070: PROJECT WORK

Students are required to undertake innovative and research oriented projects, which not only reflect their knowledge gained in the previous two semesters but also reflects additional knowledge gained from their own effort. The project work can be carried out in the institution/ industry/ research laboratory or any other competent institutions. The duration of project work should be a minimum of 36 weeks. There will be a mid-term evaluation of the project work done after about 18 weeks. An interim project report is to be submitted to the department during the mid-term evaluation. Each student has to submit to the department a project report in prescribed format after completing the work. The final evaluation and viva-voice will be after submission of the report. Each student has to make a presentation on the work carried out, before the departmental committee for project evaluation. The mid-term & end semester evaluation will be done by the departmental committee including the guides.

PROGRAM ELECTIVES

EE6240: DIGITAL SIGNAL PROCESSING & APPLICATIONS [3 1 0 4]

Introduction to Signal Processing, Review of DFS and DTFT, Computation of DFT and FFT, Introduction to linear filtering using DFT, Digital Filter Structures - direct form I and II, Cascade, Parallel, Lattice, Linear phase, Digital Filter Design - FIR filter using window function technique and frequency sampling technique, finite word length, IIR filter design with bilinear transformation technique and impulse invariant technique, Architecture of Digital Signal Processors, Application of DSP in Power Electronics Converters and Drives.

References:

1. J. G. Proakis and D.G. Manolakis, *Introduction to Digital Signal Processing* (4e), PHI, 2007
2. S. K. Mitra, *DSP: A computer based approach* (2e), TMH, 2006
3. D. O'Shaghnessy, *Speech communication – Human & Machines* (2e), Wiley-IEEE Press 1999
4. R. C. Gonzalez and Woods R. E, *Digital Image Processing*, Pearson, 2005

EE6241: DIGITAL SYSTEM DESIGN USING FPGA [3 1 0 4]

Revision of basic Digital systems - Combinational Circuits, Sequential Circuits, Synchronous FSM and asynchronous design, Metastability, Clock distribution and issues, basic building blocks like PWM module, pre-fetch unit, pre-fetch unit, programmable counter, FIFO, Booth's multiplier, ALU, Barrel shifter etc, Digital system Design - Top down Approach to Design, Verilog Synthesis for FPGA Implementation - Verilog constructs and operators, interpretation of Verilog constructs, Examples of Verilog codes for combinational and sequential logic, Data Path and Control Path Design, Programmable Logic Devices - Introduction, Evolution - PROM, PLA, PAL, Architecture of PAL's, Applications, Programming PLD's, FPGA with technology, FPGA structures, Programmable Interconnections, Coarse grained reconfigurable devices, Case study - Applications of digital system design for power electronic converters and drives. IP and Prototyping - IP in various forms: RTL Source code, Encrypted Source code, Soft IP, Netlist, Physical IP, and Use of external hard IP during prototyping, Case studies, and Speed issues, Testing of logic circuits -Fault models, BIST, JTAG interface.

References:

1. S. Palnitkar, *Verilog HDL: A Guide to Digital Design and Synthesis*, PH/Pearson, 2003
2. K. Coffman, *Real World FPGA Design with Verilog*, PH,1999
3. P. Ashenden, *Digital Design: An Embedded systems Approach using Verilog*, Elsevier, 2007
4. D. Smith, *HDL Design: A Practical Guide for Designing, Synthesizing & Simulating ASICs & FPGAs Using VHDL or Verilog*, Doone publications 1998.
5. W. Wolf, *FPGA based system design*, Pearson, 2004

EE6242: SOFT COMPUTING TECHNIQUES [3 1 0 4]

Search algorithms- heuristic and greedy search strategies, stochastic search. Game Playing Theory: Minimax Algorithm, Alpha Beta Algorithm. Knowledge and Reasoning and planning, Uncertain Knowledge and Reasoning: Probabilities, Bayesian networks, Artificial Neural Networks, Multilayer Perceptron, Gradient descent, Logistic discrimination, Single layer Perceptron, Training a perceptron, Multilayer perceptron, Back-Propagation Algorithm, Fuzzy Systems, Fuzzy Logic, Membership Functions, Fuzzy Controllers, Evolutionary Algorithms, Genetic Algorithms, Particle Swarm Optimization, Ant Colony Optimization, Metaheuristic Search, Traveling Salesman Problem, Neuro-fuzzy hybrid algorithm, genetic neuro-hybrid algorithm, fuzzy genetic-hybrid algorithm, genetic fuzzy hybrid algorithm, GA-PSO hybrid algorithm.

References:

1. J. M. Zurada, *Introduction to Artificial Neural Systems*, Jaico publication. 2016
2. T. J. Ross, *Fuzzy Logic with Engineering Applications*, MGH, 2012.
3. A. Shukla, R. Tiwari, R. Kala, *Real Life Applications of Soft Computing*, CRC Press, Taylor and Francis Group, 2010.
4. Shivanandam & Deepa, *Principles of Soft Computing*, Wiley India edition, 2009.
5. Rajasekaran and G. A. Vijayalakshmi Pai, *Neural Networks, Fuzzy Logic and Genetic Algorithms*, PHI Learning, 2003.

EE6243: POWER QUALITY ISSUES & MITIGATION [3 1 0 4]

Power Quality Issues - Terminologies, classification, causes, effects, Power Quality Monitoring - Standards, measurement techniques, PQ monitoring system, Power Quality Mitigation - Analysis and design of passive compensators, PQ enhancement using custom power devices - DSTATCOMs, DVRs, UPQCs, control and design, Power Filters - passive, active and hybrid approaches, control and design, Performance analysis of simple systems through modeling and simulation studies, design of power filters, Power quality improvement in electrical system.

References:

1. S. Santoso, H. W. Beaty, R. C. Dugan, M F. McGranaghan, *Electrical Power System Quality*, Second edition, McGraw Hill Pub, 2002.
2. H. B. Math, *Understanding Power Quality Problems*, IEEE Press, 1st Edition, 2001.
3. J. Arrillaga, *Power System Quality Assessment*, John Wiley, 2000.
4. A. Ghosh and G. Ledwich, *Power Quality Enhancement using Custom Power Devices*, Kluwer Academic Publication, 2002.
5. C. Shankran, *Power quality*, CRC Press, 2001.

EE6244: DISTRIBUTED ENERGY RESOURCES [3 1 0 4]

Energy scenario, Overview of electrical grid, introduction to distributed generation, sources of DG systems, advantages, sizing and siting of distributed generation and demand side management, power quality issues, voltage stability, storage technology for power smoothing, operation of hybrid DG systems, micro grids, types of grid integration, issues and challenges, principles of power injection, converting technologies for grid integration, AC-link integration, DC-link integration, HFAC-link integration, instantaneous active and reactive power control approach, standards and codes for interconnection, islanding operation , Life cycle costing.

References:

1. H. L. Willia and W.G. Scott, *Distributed power Generation Planning and Evaluation*, CRC Press, 2007
2. F. A. Farret and M. G. Simoes, *Integration of Alternative Sources of Energy*, Wiley Inter Science, 2008.
3. M. H. Bollen and F. Hassan, *Integration of Distributed Generation in the Power System*, Wiley IEEE Press, 2011.

EE6245: ENERGY STORAGE DEVICES [3 1 0 4]

Introduction to different energy forms - Need for Energy storage, performance indices. Mechanical energy storage, Electromagnetic energy storage. Electro-chemical storage- Electro-chemical cell, fuel cells, batteries, Battery Technologies, Fuel cells: History – principle - working - thermodynamics and kinetics of fuel cell process –performance evaluation of fuel cell – comparison on battery Vs fuel cell, Types of fuel cells – AFC, PAFC, SOFC, MCFC, DMFC, PEMFC, Hydrogen storage: Physical and chemical properties, general storage methods, compressed storage-composite cylinders, glass micro sphere storage, zeolites, metal hydride storage, chemical hydride storage and cryogenic storage, carbon based materials for hydrogen storage, hydrogen as storage medium for renewable energy systems, Pumped hydrostorage, Energy Storage Systems & applications – utilities, transport, industry, house hold, total energy system – hybrid, combined, integrated.

References:
1. Johannes, Jensen and B. Sorensen, *Fundamentals of Energy Storage*, John Wiley, 1984.
2. M. Barak, *Electrochemical Power Sources: Primary and Secondary* Batteries, IET, 1980.
3. P. D. Dunn, *Renewable Energies: Sources, Conversion & Application* (1e), IEE Energy Series, Vol. 2, Peter Peregrinus Ltd.,1986.
4. B. Sorenson, *Hydrogen and Fuel Cells: Emerging Technologies and Applications*, Academic Press (2005).
5. M. F. Hordeski, *Hydrogen and Fuel Cells: Advances in Transportation and Power*, The Fairmont Press Inc., (2009)
6. R. L. Busby, *Hydrogen and Fuel Cells: A Comprehensive Guide*, Penn Well Books, 2005.

EE6246: LIGHTING CONTROLS: TECHNOLOGY & APPLICATIONS [3 1 0 4]

Strategies and technologies - occupancy sensing, switching controls, daylight adaptation and photo sensors, Commissioning and energy codes, Controller and control algorithms - Integral reset, open-loop and closed loop control, adaptive control, predictive control , inverse control with online adaptive learning, Camera based measurement, virtual scenario based intelligent lighting control, Protocols and Networking - architecture, standard lighting protocols, wired and wireless, centralized and distributed, WSAN lighting control application, connected lighting system, SoC solutions for lighting control system, Low voltage dc systems, Power-over-Ethernet, Commissioning of smart lighting system.

References
1. Simpson, Robert S. Lighting control: technology and applications. Taylor & Francis, 2003.
2. DiLouie, Craig. Lighting controls handbook. The Fairmont Press, Inc., 2008.
3. Cai, H. "Luminance gradient for evaluating lighting." Lighting Research & Technology 48.2 (2016): 155-175.
4. Serpanos, Dimitrios, and Marilyn Wolf. Internet-of-things (iot) Systems: Architectures, Algorithms, Methodologies. Springer, 2017.
5. Yang, Kun. "Wireless sensor networks." Principles, Design and Applications (2014).

EE1247: MICROGRID [3 1 0 4]

Microgrid concept, structure and benefits, AC microgrid, DC microgrids, comparison of AC and DC microgrids, operation and control of microgrids, power electronics interfaces in DC and AC microgrids, communication infrastructure, grid connected and islanded mode of operation of microgrid, control mechanism of the connected DGs to a microgrid, techniques available for protection of microgrids, protection issues, anti-islanding schemes, power quality issues in microgrids, regulatory standards, microgrid economics, introduction to smart microgrids, hydrogen microgrid, current challenges in microgrid research and development, microgrids versus virtual power plants.

References:
1. N. Hatziargyriou, *Microgrids Architectures and Control*, John Wiley and Sons Ltd, 2014.
2. S. Chowdhury, S. P. Chowdhury and P. Crossley, *Microgrids and Active Distribution Networks*, IET, 2009.
3. M. Sechilariu and F. Locment, *Urban DC Microgrid, Intelligent Control and Power Flow Optimization* (1e), Elsevier, 2016

OPEN ELECTIVES

EE6280: INTELLIGENT CONTROL SYSTEMS [3 0 0 3]

Fundamentals of Artificial Neural Networks - Feed forward and feedback networks, learning rules, Single layer feed forward networks, Multilayer feed forward networks, Linearly non-separable pattern classification, generalized delta learning rule, error back propagation training algorithms, Single layer feedback network - Energy function, Application of neural networks, Introduction to Fuzzy control, Inference rules, Fuzzy knowledge based controllers, Fuzzification, membership function evaluation, Defuzzification methods, Application of fuzzy logic to control systems, fuzzy-neural systems, Introduction to Genetic Algorithms.

References:
1. J. S. T Jang, C.T Sun and E. Mitzutani, Neuro-Fuzzy and Soft Computing, Prentice Hall International, 2011.
2. Chin-Teng Lin, C. S. George Lee, *Neural Fuzzy Systems*, Prentice Hall International,1996.
3. S. Haykin, *Neural Networks - A Comprehensive Foundation* (2e), Prentice Hall, 2005.
4. T. J. Ross, *Fuzzy Logic with Engineering Applications*, MGH, 2014.
5. J. M. Zurada, *Introduction to Artificial Neural Networks*, Jaico, 2016.

EE 6281: PHOTOVOLTAIC SYSTEMS [3 0 0 3]

Basic characteristics of sunlight, Solar PV cell, I-V characteristics, P-V characteristics, fill factor, Modeling of solar cell, maximum power point tracking, PV module, blocking diode and bypass diodes, composite characteristics of PV module, PV array, PV system design, Applications – PV powered fan, PV fan with battery backup and charge controllers, PV powered pumping system, PV powered lighting systems, grid connected PV systems, Simple payback period, life cycle costing.

References:

1. C. S. Solanki, Solar Photovoltaic's: Fundamentals, Technologies and Applications (2e), PHI Learning Publications, 2011.
2. R. A. Messenger and J. Ventre, Photovoltaic systems engineering (2e), Taylor and Francis Group Publications, 2003.
3. G. N. Tiwari, *Solar Energy: Fundamentals, Design, Modeling and Applications*, Narosa Publications New Delhi, 2013.
4. S. Deambi, *Photovoltaic System Design*, CRC Press USA, 2016.
5. J. Balfour, M. Shaw and N. B. Nash, *Advanced Photovoltaic Installations*, Jones & Barlett Learning USA, 2013.