I SEMESTER

21ED01 MATHEMATICS OF SYSTEMS ENGINEERING

Vide Applied Electronics 21EA01

21ED02 POWER SEMICONDUCTOR DEVICES

3 0 0 3

INTRODUCTION & POWER DIODES: Status of Development of power semiconductor Devices - Types of static switches - Controlled and uncontrolled - Ideal and real switches – on-state and switching losses. EMI due to switching. Heat sinks – selection and mounting techniques. Power diodes: General terms - Structure and functional principle - Static behaviour - Dynamic behaviour – datasheet ratings – switching loss calculations. Freewheeling and snubber diodes:Schottky diodes – PIN diodes. (11)

THYRISTORS: Thyristors – types - Symbols and Terminology - Theory of Thyristor Operation - Thyristor Drivers and Triggering- Protection- SCR Characteristics – datasheet ratings – switching loss calculations – Applications.TRIACS, GTOS AND MCTS: datasheet ratings - Switching and steady state characteristics - Protection - Gate circuit requirements. (11)

POWER TRANSISTORS & IGBTs: Power Transistors, Power MOSFETS, IGBTs : types - Structure and functional principle - Static behaviour - Dynamic behaviour – protection – driver circuits - datasheet ratings – switching loss calculations. Comparison of Power Transistors, Power MOSFETS, IGBTs. (11)

IPMs& WIDEBAND GAP DEVICES: IntelligentPower Modules (IPMs) - Structure of IPMs - IPM Ratings and Characteristics - Area of Safe Operation for IPMs - IPM Self Protection - IPM Selection – Controlling the IPMs – interpretation of data sheets of IPMs – IPM packaging types. New wide band gap devices: Introduction – Existing Si devices and its limitations - Motivation for high-speed switching devices - Properties and types of wide-bandgap semiconductors -SiC and GaN device technology and device characterization - Power converter realizations with Sic and GaN - Benefit analyses. (12)

Total L: 45

REFERENCES:

1. Baliga, B. Jayant.,"Fundamentals of power semiconductor devices", Springer Science & Business Media, 2010.
2. Perret, Robert, ed.,"Power electronics semiconductor devices", John Wiley & Sons, 2013.
3. Ned Mohan, Tore M. Undeland and William P. Robbins., "Power Electronics: Converters, Applications and Design", John Wiley and Sons, 3rd Edition, 2003.
4. Rashid, Muhammad H. Power electronics handbook: devices, circuits and applications. Elsevier, 2010.
5. Takahashi, Kiyoshi, Yoshikawa, Akihiko, Sandhu, Adarsh, "Wide Bandgap Semiconductors", Springer,1st Edition, 2007.

21ED03 MODELING AND ANALYSIS OF ELECTRICAL MACHINES

3 0 0 3

GENERALIZED THEORY & LINEAR TRANSFORMATION: Conversions – Basic two pole machine – Transformer with movable secondary – Transformer voltage and speed voltage - Kron's primitive machine - Invariance of power – Transformation from displaced brush axis three phases to two phases. Rotating axes to stationary axes – Transformed impedance matrix – Torque calculations. (11)

INDUCTION MACHINES: Generalized representation- Performance equations - Steady state analysis – Equivalent circuit and Torque Analysis – Effect of Voltage and frequency variation -Induction motor dynamics – starting, breaking and normal operation - Single- phase Induction motor- cross field theory - Harmonics. (12)

SYNCHRONOUS MACHINES: Generalized representation - Steady state analysis- Phasor diagram – Regulation – Power angle characteristics - Short circuit ratio - Transient analysis (Qualitative approach) (11)

DC & SPECIAL MACHINES: Generalized representation – Operation with displaced brushes - Motor (shunt type only) operation - Steady state and transient analysis. Generalized representation and steady state analysis of Reluctance motor – Brushless DC motor-Variable reluctance motor. (11)

Total L: 45

REFERENCES:

1. Bimbhra P.S., "Generalised Circuit Theory of ElectricalMachines", Khanna Publishers, Delhi, 5th edition, Reprint 2012
2. Mittle V N, Mittal A., "Design of electrical machines",Standard Publishers Distributors,New Delhi, 2002.
3. Kothari, D.P. and Nagrath, I.J., "Electric machines",Mcgraw Hill Education (I) P Ltd., 2018.
4. Krishnan R., "Electric Motor & Drives: Modeling, Analysis and Control", Prentice Hall ofIndia, 2001.
5. Boldea, Ion, and Lucian Tutelea., "Reluctance electric machines: design and control", CRC Press, 2018.

21ED04 POWER CONVERTERS AND ANALYSIS

3 1 0 4

AC TO DC CONVERTERS: Design and analysis of Single phase and three phase bridge rectifiers, Fully controlled converters with RL, RLE loads, Freewheeling diode, Dual Converter, PWM rectifiers, Input harmonics and output ripple, smoothing inductance, power factor, effect of source inductance and overlap, Design of converter circuits – Snubber circuit design - Control circuit strategies. (12+4)

DC TO DC CONVERTERS: DC choppers: Step down dc chopper with R, RL and RLE loads - Control strategies- Continuous and discontinuous current operations - Two quadrant and four quadrant DC chopper - Multiphase DC chopper - Switching mode regulators: Buck, Boost, Buck-Boost and CUK regulators - Chopper circuit design – Control circuit strategies. (11+4)

AC TO AC CONVERTERS: Principle of phase control, single-phase bi-directional controllers with R, L and R-L loads, 3-phase bi-directional Controllers, different Configurations, Analysis with pure R and L loads. Principle of operation, - single phase and three phase cyclo converters - Control circuit strategies. (11+3)

DC TO AC CONVERTERS: Single phase and Three phase bridge inverters - Evaluation of performance parameters –Voltage control and Waveform improvement Techniques – Current source inverters - Inverter circuit design - SVPWM – Introduction to multilevel inverter. (11+4)

Total L: 45 + T: 15 = 60

REFERENCES:

1. Rashid M.H., “Power Electronics Circuits, Devices and Applications ", Prentice Hall India,3rd Edition, New Delhi, 2013.
2. Sen PC,"Modern Power Electronics ", Wheeler publishing Co, McGraw Hill, 2005.
3. Ned Mohan, Tore M. Undeland, William P. Robbins, ”Power Electronics: Converters, Applications, and Design”, John Wiley and Sons, Inc., New York, 2003.
4. MD Singh and K B Khanchandani,"Power Electronics" McGraw Hill, 2006.
5. Soumitra kumar Mandal, "Power Electronics", McGraw Hill Education, 2017.

21ED05 MODELING AND SIMULATION OF POWER ELECTRONIC CONVERTERS

3 1 0 4

MODELING OF POWER ELECTRONIC CONVERTERS: Requirements of Modeling and Control of Power Electronic Converters - Types of model - State Space Averaging - Circuit Averaging and Averaged Switch Modeling - Converter Transfer Functions for Buck - Boost and Buck-Boost Topologies - Averaging Power System Dynamics -Circuit Averaging Technique - Linearizing Averaged Power Stage Dynamics - Case studies. (12+4)

LINEAR CONTROL APPROACHES FOR DC-DC POWER CONVERTERS: General Control Principles Control Goals and Control Issues of Power Electronic Converters - Direct Output Control: Assumptions and Design Algorithm - Indirect Output Control: Two-Loop Cascaded Control Structure for DC-DC Converters with Non-minimum Phase Behaviour - Converter Control using Dynamic Compensation by pole placement - Digital Control Design Approach - Case studies. (11+4)

LINEAR CONTROL APPROACHES FOR DC-AC AND AC-DC POWER CONVERTERS - Issues - Control in Rotating dq Frame - Resonant Controllers: Necessity of Resonant Control - Proportional Resonant Control - Design Methods - Implementation Aspects - Control of Full Wave Converters - Case Studies. (11+3)

NONLINEAR CONTROL : Need for Non linear control - Lyapunov Approach - Overview of Nonlinear Control Methods for Power Electronic Converters. Basic sliding mode control theory- PWM-based sliding mode control schemes for DC/DCpower converters: PWM-based Sliding Mode Voltage and Current Control - Practical Implementation and Design Issues. (11+4)

Total L : 45 + T: 15 = 60

REFERENCES:

1. Farret, Felix A, Simoes, M. Godoy, "Control of Power Electronic Converters and Systems", Vol. 3, Academic Press, 2018.
2. Miguel Castilla, " Control Circuits in Power Electronics - Practical Issues in Design and Implementation", Institution of Engineering and Technology, 2016.
3. Seddik Bacha, Iulian Munteanu, Antoneta Iuliana Bratchu, "Power Electronic Converters Modeling and Control with Case Studies", Springer London 2014
4. Byungcho Choi,Pulsewidth Modulated DC-to-DC Power Conversion Circuits, Dynamics, and Control Designs, IEEE Press, John Wiley & Sons. Inc, 2013.
5. M Gopal “Modem Control System Theory”, New Age International,2011.

21ED06 / 21EE06 / 21EA06 / 21EM06 RESEARCH METHODOLOGY AND IPR

vide Automotive Engineering 21AE06

21ED72 AUDIT COURSE I

vide Automotive Engineering 21AE72

21ED51 POWER CONVERTERS LABORATORY

0 0 4 2

LIST OF EXPERIMENTS:

1. Study of Characteristics of Power Semiconductor Devices.
2. Performance analysis of AC to DC converter with RL and RLE Load
3. Performance analysis of AC to AC converter with RL and RLE Load
4. Performance analysis of DC to DC converter with RL and RLE Load
5. Performance analysis of DC to AC converter under voltage and v/f control mode.
6. Mini project

Total P: 60

21ED52 / 21EA51 / 21EE52 OBJECT COMPUTING AND DATA STRUCTURES LABORATORY

0 0 4 2

Object Computing (Using C++):
Implementation of the following problems:

1. Implementation of classes and object for simple arithmetic operations.
2. Implementation of array of objects and dynamic objects.
3. Implementation of Static members.
4. Implementation of call by value, call by reference and return by reference.
5. Implementation of friend functions, inline functions and default arguments.
6. Implementation of constructors and destructors.
7. Implementation of inheritance and its types
8. Implementation of polymorphism and its types.

Data Structures (Using C or C++):

1. Program using arrays.
2. Representation of Sparse & dense Matrix using arrays.
3. Implementation of Stacks using array.
4. Application of Stack: Conversion of infix to postfix expression
5. Implementation of queue using array.
6. Implementation of Linked Lists: Singly linked, doubly linked and Circular lists and applications.
7. Implementation of various sorting algorithms.

Total P: 60

REFERENCES:

1. Herbert Schildt, “C++ - The Complete Reference", Tata McGraw Hill, New Delhi, 2012.
2. Aaron M Tanenbaum, Moshe J Augenstein and YedidyahLangsam, "Data structures using C and C++", Pearson Education, New Delhi, 2009.
3. Harvey M Deitel,andPaul J Deitel, “C++ How to Program”, Prentice Hall, New Delhi, 2010.
4. Robert L Kruse, Bruce P Leung and Clovin L Tondo, “Data Structures and Program Design in C”, Pearson Education, New Delhi, 2009
5. Mark Allen Weiss, “Data Structures and Algorithm Analysis in C”, Pearson Education, New Delhi, 2007.

II SEMESTER

21ED07 ELECTRIC DRIVES AND CONTROL

3 1 0 4

DYNAMICS & CONTROL OF ELECTRICAL DRIVES: Introduction – Parts of Electrical Drives- Fundamental Torque Equations – Speed Torque Conventions and Multiquadrant Operation – Nature & Classification of Load Torques - Modes of Operation – Closed-Loop Control of Drives– Classes of Motor duty cycles. (10+3)

Induction Motor Drives: Stator Control: control by AC voltage controllers - Variable frequency square wave VSI drives - PWM Drives - CSI drives - closed loop control. Rotor Control**:** Static rotor resistance control - Slip power recovery : Static Kramer drive -Static Scherbius drive. (11+4)

VECTOR CONTROL OF INDUCTION MOTORS: Principle of vector control -Rotor flux - Oriented control, Stator Flux-oriented control, Magnetizing flux-oriented control of Induction machines. Sensorless Vector and Direct Torque Controlled Drives. (12+4)

SPECIAL ELECTRIC DRIVES& CONTROLS: Synchronous Motor Drives: True synchronous and self-control modes – Performance analysis of PMSM, BLDC, SynRM, Switched Reluctance Motor: drive operations, rotor position sensing mechanisms and controls.Configurations of I/O Control: 3-phase VFD drive Hardware Blocks – Control Blocks – Automatic Motor Adaptation for Induction, PMSM and SynRM Drives – Parameterization of Drives (Local and Remote) (12+4)

Total L : 45 + T: 15 = 60

REFERENCES:

1. Gopal K Dubey, "Fundamentals of Electric Drives", Narosa Publishing House, New Delhi , 2005.
2. Boldea, Ion, and Syed A. Nasar,"Electric drives", CRC press, 2016.
3. Krishnan, Ramu "Permanent magnet synchronous and brushless DC motor drives", CRC press, 2017..
4. Bose, Bimal K. "Power electronics and motor drives: advances and trends", Elsevier, 2010.
5. Nasar, SyedA. "Vector control of AC drives", Routledge, 2017.

21ED08 SWITCHED MODE POWER CONVERTERS

3 1 0 4

DC-DC CONVERTER DYNAMICS: Reactive Elements in Power Electronic Systems, Types of inductor, Types of transformer, Types of Capacitors for power electronic applications - Exact and Approximate Analysis of DC-DC converters, Design and analysis, steady state and dynamic model of Non-isolated DC to DC Power Converter- Buck, Boost, Buck-Boost, Cuk Converters, Isolated DC to DC Power Converter - Forward, Flyback, Half/Full Bridge Converters - Case Study - EMI-EMC Complaints. (12+3)

RESONANT CONVERTERS: Classification of resonant converters-resonant load converters- principal of operation- SMPS using resonant circuit- steady state modeling. Resonant switch converters- Buck converter with ZCS and ZVS-operation and analysis. (11 +4)

CLOSED LOOP CONTROL OF POWER CONVERTERS: Closed Loop Control of Switching Converters- Steady State Error, Control Bandwidth, and Compensator Design- Closed Loop Dynamic Performance Functions- Design of feed- back compensators. (11+4)

AC-DC POWER FACTOR CORRECTION SUPPLIES: Single-Phase Single-Stage Non-isolated Boost PFC, Output Capacitor Size, DCM Boost Inductor Selection, CCM Boost Inductor Selection, High-Power PFC and Load Sharing, Surge Protection, Load Short-Circuit Protection, Three-Phase PFC. (11+4)

Total L: 45 + T: 15 = 60

REFERENCES:

1. Keng Wu, "Switch-Mode Power Converters-Design and Analysis", 1st Edition, Academic Press, 2005.
2. Byungcho Choi, Pulsewidth Modulated DC-to-DC Power Conversion Circuits, Dynamics, and Control Designs, IEEE Press, Wiley, 2013.
3. Marian K. Kazimierczuk, "Pulse-width Modulated DC-DC Power Converters", Wiley, 2008.
4. Ramanarayanan V., "Course Material on Switched Mode Power Conversion", Department of Electrical Engineering, Indian Institute of Science, Bangalore, 2007.
5. Mohan, N., Undeland, T. M., & Robbins, W. P. "Power electronics: converters, applications, and design", John wiley & sons, 2003.

21ED82 AUDIT COURSE II

vide Automotive Engineering 21AE82

21ED61 DRIVES AND CONTROLS LABORATORY

0 0 4 2

LIST OF EXPERIMENTS:

1. Performance analysis of three phase induction motorusing variable frequency drive
2. Performance analysis of Synchronous Reluctance and PMSM motor using variable frequency drive
3. Performance analysis of SRM/BLDC motor using variable frequency drive
4. Harmonic analysis of variable frequency drives using scalar and vector control
5. Hardware-in-loop simulation of Electric Drives using Opal-RT and dSPACE.
6. Mini project

Total P: 60

21ED62 POWER ELECTRONIC SYSTEMS DESIGN LABORATORY

0 0 4 2

LIST OF EXPERIMENTS:

1. Design, development and analysis of DC to DC converters using IGBTs, and Power MOSFETs.
2. Design and development of DC to AC converters using IGBTs, and Power MOSFETs.
3. Design, development and analysis of AC to AC converters of various configurations using SCRs, TRIAC, and IGBTs.
4. Design, development and analysis of AC to DC converters using SCR and Diodes.
5. Hardware-in-loop simulation of Power Converters using Opal-RT and dSPACE.
6. Mini project

Total P: 60

21ED63 INDUSTRIAL VISIT AND TECHNICAL SEMINAR

vide Automotive Engineering 21AE63

SEMESTER – III

21ED71 PROJECT WORK – I

vide Automotive Engineering 21AE71

SEMESTER – IV

21ED81 PROJECT WORK – II

Vide Automotive Engineering 21AE81

PROFESSIONAL ELECTIVE THEORY COURSES (Four to be opted)

21ED21 POWER ELECTRONICS IN RENEWABLE ENERGY SYSTEMS

3 0 0 3

SOLAR PV AND WIND POWER : Trends in energy consumption - World energy scenario – Energy sources and their availability - Conventional and renewable sources - Solar PV and Wind potential in India and World – Solar and Wind Data - Policies and Regulations - Standards and codes used for Renewable Energy Systems. (11)

SOLAR PHOTOVOLTAIC ENERGY CONVERSION: Solar radiation and measurement - Solar cells and their characteristics - Classification of Solar PV panels- Influence of insolation and temperature - PV arrays- Maximum power point tracking – Algorithms Power Conditioning Schemes - Charge controllers - Inverters – Classifications and Design - Analysis of PV Systems – BoS components - Stand alone and Grid integrated Solar PV Systems – Building Integrated PV (BIPV) - Synchronized operation with grid supply - Harmonic standards, Harmonic problems. (12)

WIND ENERGY CONVERSION SYSTEMS: Basic Principle of wind Energy conversion - Nature of Wind - Power in the wind - Components of Wind Energy Conversion System (WECS) – Wind farm and its accessories - Generators used in Wind Energy Conversion Systems - Performance of Induction Generators for WECS- Power conditioning schemes - Controllable DC Power from SEIGs - System performance. Grid Connected WECS - Concepts of Grid Integration - Grid related problems - Generator control - Performance improvements - Different schemes - AC voltage controllers - Harmonics and PF improvement. (11)

HYBRID POWER SYSTEMS: Wind / Solar PV integrated systems – Other alternate Systems – Requirements - Optimization of system components Power conditioning schemes for Hybrid Power Systems (HPS) – Design of HPS using software - Storage types and selection methods - Applications of HPS (11)

Total L : 45

REFERENCES:

1. Mukund R Patel, “Wind and Solar Power Systems”, CRC Press, 2004.
2. Rai, G.D., "Non-conventional Energy Sources", Khanna Publishers, New Delhi, 2002.
3. Ackermann, Thomas, ed.,“Wind power in power systems”, Vol. 140, Chichester, UK: John Wiley, 2005.
4. S Sumathi, Ashok Kumar L, S Sureka, “Solar PV and Wind Energy Conversion Systems - An Introduction to Theory, Modeling with MATLAB/SIMULINK, and the Role of Soft Computing Techniques”, Green Energy and Technology, Springer; 2015.
5. Thomas Markvart and Luis Castaser, “Practical Handbook of Photovoltaics”, Elsevier Publications, UK, 2003.

21ED22 INDUSTRIAL APPROACH TO POWER CONVERTER DESIGN

3 0 0 3

NEW PRODUCT DEVELOPMENT : Introduction - Product Development Process -Phases and Stages Gates Model, Product Specification - Subsystem Specification - Sub-system Design - Design Verification - Prototype Development - Engineering Verification– Product cost - Design to Cost - Price and Cost - Cost Estimation methods.
Power Converter Circuit and PCB Assembly– Introduction to New wide band gap devices –device characterization - Existing Si devices and its limitations - - Power converter prototypes with GaN - Benefit analyses (cost, performance and size) —PCB Assembly - Material Selection - PCB Layout and Assembly - Thermal Design - Packaging Design – Prototyping.
Battery – Types – Charging Circuit – Health monitoring – Sizing Techniques (11)

EMBEDDED SYSTEM : Embedded Systems Development Life Cycle - Functional Block Diagram - System Architecture - Control Architecture - Communication Architecture - Firmware Architecture - Firmware Requirement Specifications - Microcontroller Selection - Microcontroller Architecture - Driver Development - Scheduler and Interrupt Design - Digital Control Methods - Power Converter Control Methods - Digital Implementation of Controller - State Machine Design (11)

DESIGN VERIFICATION AND REGULATORY COMPLIANCE : Verification and ValidationProcess -Types of Verification - Case Study –Design Verification Test for power converters - Design Verification and Validation (DVT) Automation - Field Issues and Handling - Service Log - Conditions for Serviceability - Remote Monitoring, Control and performance check - , Worst Case Analysis- Vulnerability conditions and Warranty definitions.

Product Quality - Regulatory Compliance and Safety - ESD&EMI/EMC - Environmental Regulations - Audible Noise – Reliability - Fault Detection & Isolation - Quality management Workflow (12)

MANUFACTURING AND INDUSTRIALIZATION : Product Designation - Manufacturing - Operational map - Industrialization Project Follow-Up - PCBA Design - Make or Buy Analyses - Industrial Expenses - PCBA process - Failure Mode Effects Analysis (FMEA) - Manufacturing Tools & Equipment Producing - PCBA Cost Assessment -Design for Manufacturing - Design for Test - Design for Procurement - Part/Product Evaluation Plan - EP Boards Manufacturing- Incoming Inspection Sheet - Pilot Run Boards Manufacturing - Mass Production - Diagnosis and Failure Analysis (11)

Total L: 45

REFERENCES:

1. Rose, Kenneth H. "A guide to the project management body of knowledge (PMBOK® Guide)—Fifth Edition." Project Management Institute, 2013.
2. Mohan, Undeland and Robbins, Power Electronics: converters, applications and design, 3nd ed. John Wiley & Sons, 2003
3. Mohammed Rashid, Power electronics : circuits, devices, and applications, 3rd ed., Prentice-Hall, 2004
4. V. Kumar, R.R. Joshi, and R.C. Bansal, Advanced Power Electronics, Ashirwad Publications, Jaipur, India, Feb. 2010.
5. Andrzej M Trzynadlowski, Introduction to Modern Power Electronics, Wiley, 2010

21ED23 / 21EE21 / 21EM23 INTERNET OF THINGS

3 0 0 3

FUNDAMENTALS OF IoT: Introduction to Internet of Things (IoT) – Machine to Machine (M2M) – Functional Characteristics – Recent Trends in the Adoption of IoT – Societal Benefits of IoT – Consumer IoT vs Industrial Functional Components of a typical IoT System: Sensors, Actuators, Embedded Computation Units, Communication Interfaces , Software Development.(11)

IoT PROTOCOLS: Physical and Data Linnk Layer Protocols: RFID: NFC, FFC, ZigBEE, Bluetooth Low Energy, Z-Wave, Wi-Fi, LoRA - Network Layer Protocols: IPv4, IPv6, TCP & UDP, 6LoWPAN - Application Layer Protocols: COAP, MQTT (12)

CLOUD COMPUTING: NIST Visual Model – Essential Characteristics –Components of Cloud Computing - Service Models – Deployment Models – Service Management and Security – Examples – Basics of Fog Computing (11)

SECURITY and APPLICATIONS: IEEE 802.11 Wireless Networks Attacks: Basic Types, RFID Security – Security Issues in ZigBEE: Bluetooth Security: Threats to Bluetooth Devices and Networks - IoT Applications**:** Health Care, Connected Vehicles, Smart Grid, Smart Home, and Smart City. (11)

Total: L:45

REFERENCES:

1. Adrian McEwen and Hakim Cassimally, “Designing the Internet of Things”, John Wiley and Sons Ltd, UK, 2014.
2. Olivier Hersent, David Boswarthick and Omar Elloumi, “The Internet of Things: Key Applications and Protocols”, John Wiley and Sons Ltd., UK 2012.
3. Dieter Uckelmann, Mark Harrison, Florian Michahelles, “Architecting the Internet of Things”, Springer, New York, 2011.
4. Johnny Cache, Joshua Wright and Vincent Liu, “Hacking Exposed Wireless: Wireless Security Secrets and Solutions”, Tata McGraw Hill, New Delhi, 2010.
5. Himanshu Dwivedi, Chris Clark and David Thiel, “Mobile Application Security”, Tata McGraw Hill, Nw Delhi, 2010.

21ED24 / 21EE22 TOTALLY INTEGRATED AUTOMATION

3 0 0 3

INTRODUCTION TO FACTORY & PROCESS AUTOMATION: Evolution of Industrial Versions - Control elements of Industrial Automation- IEC/ ISA Standards for Control Elements – Selection criteria for control elements –Utilisation Category with IEC standards- Construction of Relay Ladder logic with different control elements- Need for PLC - PLC evolution. (6)

PROGRAMMABLE LOGIC CONTROLLERS: Architecture of PLC - Types of PLC – PLC modules, PLC Configuration -Scan cycle - Capabilities of PLC- Selection criteria for PLC – PLC Communication - PLC Wiring- Installation of PLC and its Modules. Types of Programming – Bit Instructions -Timers and counters– PLC arithmetic functions PTO / PWM generation- High Speed Counter – Analog Scaling – Encoder Interfacing- Servo drive control – Stepper Motor Control. (12)

HMI SYSTEMS & NETWORKING: Need for HMI in Industrial Automation, Types of HMI – Configuration of HMI, Screen development and navigation, Configuration of HMI elements / objects and Interfacing with PLC. PLC Networking- Networking standards & IEEE Standard - Protocols - Field bus - Process bus and Ethernet –EttherCAT (13)

SUPERVISORY CONTROL AND DATA ACQUISITION: Architecture – Tools – Tag Configuration - Internal & External graphics, Alarm logging – Tag logging – structured tags – Trends – history – Report generation (14)

Total L:45

TEXT BOOKS:

1. W. Bolton, Programmable logic controllers, Elsevier Ltd, 2015.
2. Frank D Petruzella, Programmable logic controllersǁ, McGraw-Hill, 2011.
3. John R Hackworth and Fredrick D Hackworth Jr., ―Programmable Logic Controllers: Programming Methods and Applicationsǁ, Pearson Education, 2006.
4. Working with WinCC, Software manual, Siemens, 2015.
5. CIMPLICITY SCADA Packages Manual, Fanuc India Ltd 2004.

21ED25 SPECIAL MACHINES AND CONTROLLERS

3 0 0 3

INTRODUCTION: Need for special electric machines and controllers– Special Applications requirement– Robotics, Aerospace actuators, space explorations roverand high temperature environments. Stepper Motors: Types – Constructional features, principle of operation– modes of excitation–torque production in Variable Reluctance (VR) stepper motor, Permanent Magnet & Hybrid stepper, Static&dynamic characteristics – Speed-Torque characteristics – Drive systems and circuit – introduction, unipolar drive & bipolar drive circuits, open loop and closed loop control of stepper motor. (11)

SWITCHED RELUCTANCE MACHINES: constructional features, principle of operation, Torque equationand characteristics control techniques – Inductance Profile – Commutation timing diagram – starting & running phase excitation – speed controls, general controller structure– determination of rotor position, current profiling for smoother torque. Synchronous Reluctance Machines:Synchronous reluctance motor(SynRM) - operating principle, rotor topologies - Space-vector diagram - basic characteristics of SynRM - Control of SynRM - Power factor, Current angle, saliency ratio– Vector control - constant current control, constant angle control– Development of Permanent Magnet assisted SynRM (12)

PERMANENT MAGNET BRUSHLESS DC MACHINES: Commutation in DC motor, Electronic commutation, Hal sensors, Optical sensors, Magnetic circuit model, Multiphase Brushless motor, Square wave permanent magnet brushless motor drives, Torque and emf equation, Torque-speed characteristics,Control by Back-EMF detection circuits, Controllers-Microprocessor based controller, Field Weakening control. (11)

PERMANENT MAGNET SYNCHRONOUS MACHINES: Introduction -Motor Morphologies -Principle of operation, EMF, power input and torque expressions, Phasor diagram, Torque -speed characteristics -Parameter Estimation Power controllers, Torque Controllers, , Self-control, Vector control, Current control schemes. Linear Motors:Linear Induction motor (LIM) classification - construction - Principle of operation - concept of current sheet - goodness factor - DC Linear motor (DCLM) types - circuit equation - DCLM control applications. (11)

Total L : 45

REFERENCES:

1. Paul Acarnley, “Stepping Motors a guide to theory and practice” IET, 2007
2. Riazollah Firoozian, “Servo Motors and Industrial Control Theory”, Springer, 2014.
3. JuhaPyrhonen, Valeria Hrabovcova, Scott semken, “Electrical Machines Drives Control – An Introduction”, Wiley, 2016
4. Krishnan, R., “Permanent magnet synchronous and brushless DC motor drives”, CRC press, 2017.
5. Boldea, Ion., “Linear electric machines, drives, and MAGLEVs handbook”, CRC press, 2017.

21ED26 / 21EE43 / 21EM26 DIGITAL CONTROLLER FOR POWER ELECTRONICS

3 0 0 3

TMS C2XX DSP : Introduction to the C2xx DSP core and code generation. The components of the C2xx DSP core, Peripherals and Peripheral Interface, System configuration registers, Memory , Types of Physical Memory , memory Addressing Modes , Code Composer Studio for C2xx DSP. (12)

I/O AND INTERRUPTS: Pin Multiplexing (MUX) and General Purpose I/O Overview, Multiplexing and General Purpose I/O Control Registers, Programming I/O. Introduction to Interrupts, Interrupt Hierarchy, Interrupt Control Registers, Initializing and Servicing Interrupts in Software, Programming Interrupts (11)

ADC AND EVENT MANAGERS: ADC Overview , Operation of the ADC in the DSP , Overview of the Event manager (EV), Event Manager Interrupts , General Purpose (GP) Timers , Compare Units, Capture Units And Quadrature Enclosed Pulse (QEP) Circuitry, General Event Manager Information, Programming of ADC and Event Managers (11)

DESIGN OF CONTROLLER IN POWER ELECTRONICS: Typical applications: DSP-based implementation of DC-DC buck-boost converter- DSP-based control of permanent magnet brushless DC machines- DSP-based Implementation of clarkes's and park's transformations- DSP-Based implementation of SPWM, SVPWM inverter pulse generation. (11)

Total L: 45

REFERENCES:

1. Hamid.A.Toliyat and Steven G.Campbell "DSP Based Electro Mechanical Motion Control" CRC Press New York, 2004.
2. TMS320C28x CPU and Instruction Set Reference Guide -SPRU430
3. TMS320x28xx, 28xxx Peripheral Reference Guide -SPRU566
4. TMS320x2833x System Control and Interrupts Reference Guide -SPRUFB0
5. TMS320x2833x Analog-to-Digital Converter (ADC) Reference Guide -SPRU812

21ED27 / 21EM27 ADVANCED CONTROL OF ELECTRIC DRIVES

3 0 0 3

ADVANCED CONTROL OF POWER CONVERTERS: Introduction - Power Converter Control using State-Space Averaged Models - Sliding-Mode Control of Power Converters - Fuzzy Logic Control of Power Converters. (11)

DSP CONTROLLED DRIVES: Types of Torque-Controlled Drive Schemes - Vector Drives, Direct-Torque-Controlled Drives – DSP Controlled AC Drive, Synchronous motor Drive, and BLDC Motor drive. (12)

FUZZY CONTROLLED DRIVES: Induction Motor Drives, Synchronous Motor Drives, Reluctance motor Drives, Servo Motor Drives: Speed control using Fuzzy logic based digital controllers (11)

ARTIFICIAL-INTELLIGENCE BASED DRIVES: AI-Based Techniques - Applications in Electrical Machines and Drives –Neural Networks based control of AC Drive, SynRM Drive, and BLDC Motor drive (11)

Total L: 45

REFERENCES:

1. Marcian Cirstea, Andrei Dinu, Malcolm Mc Cormick, Jeen Ghee Khor, "Neural and Fuzzy Logic Control of Drives and Power Systems, Newnes Publications, 2002.
2. Krishnan, R.,"Electric motor drives: modeling, analysis, and control", PHI Learning Pvt Ltd.,New Delhi, 2014.
3. Hamid A Toliyat and Steven G. Campbell, "DSP Based Electromechanical Motion Control", CRC Press, 2004.
4. Mohan, Ned.,"Advanced electric drives: analysis, control, and modeling using MATLAB/Simulink", John wiley & sons, 2014.
5. Hamid.A.Toliyat and Steven G.Campbell "DSP Based Electro Mechanical Motion Control" CRC Press New York, 2004.

21ED28 / 21EM28 SOFT COMPUTING TECHNIQUES FOR RENEWABLE ENERGY SYSTEMS

3 0 0 3

INTRODUCTION TO SOFT COMPUTING TECHNIQUES: Fundamentals – Biological neural network – Artificial neuron – Activation function – Learning rules - Single Layer Feedback Networks - Unsupervised Learning Networks - Membership Functions - Features of membership function - Standard forms and Boundaries - fuzzification - membership value assignments - Evolutionary Computation Techniques - Fundamentals of evolutionary algorithms-principle of simple Genetic Algorithm-selection, crossover and mutation. (11)

OPTIMISATION TECHNIQUES FOR PHOTOVOLTAIC ENERGY CONVERSION: Passive filter design using Genetic Algorithm, harmonic elimination in inverters, Tuning of controllers, GA, PSO, DE, optimized fuzzy logic for the Maximum Power Point Tracking. (11)

OPTIMISATION TECHNIQUES FOR WIND ENERGY CONVERSION SYSTEMS: Simulation model of Wind turbine and Wind Turbine Generators. Prediction of Wind Turbine Power Factor, Pitch Angle Control, MPPT Algorithms, Economic Dispatch For

Wind Power System –FLC based STATCOM - Prediction of Wind Speed based on FLC - Fuzzy Logic Controlled SPWM Converter for WECS. (11)

SOFT COMPUTING TECHNIQUES FOR HYBRID ENERGY SYSTEMS: Need for hybrid energy system, Simulation models of Hybrid Solar PV and Wind Energy System - CUK-SEPIC converter, Boost Converter, Hybrid model of Solar PV and Diesel Energy System– Hybrid Solar PV and Wind Energy Conversion Systems. (12)

Total L: 45

REFERENCES:

1. Laurene Fausett, "Fundamentals of Neural Networks", Pearson Education India, New Delhi, 2004.
2. Randall Shaffer., "Fundamentals of Power Electronics with MATLAB" Charles River Media Boston Massachusetts, 2007.
3. Rao S S., "Optimization Theory and Applications", Wiley Eastern Limited, New Delhi, 2003.
4. S. Sumathi, Ashok Kumar.L, P.Sureka, "Solar PV and Wind Energy Conversion Systems - An Introduction to Theory, Modeling with MATLAB/SIMULINK, and the Role of Soft Computing Techniques" – Green Energy and Technology, Springer, 2015.
5. Thomas Markvart and Luis Castaser, "Practical Handbook of Photovoltaics", Elsevier Publications, UK, 2003

21ED29 FLEXIBLE AC TRANSMISSION SYSTEM

3 0 0 3

INTRODUCTION: Power flow in Power Systems – Steady-state and dynamic problems in AC systems – Voltage regulation and reactive power flow control in Power Systems – Power flow control -Constraints of maximum transmission line loading - Benefits of FACTS .Transmission line compensation- Uncompensated line -shunt compensation - Series compensation–Phase angle control .Reactive power compensation – shunt and series compensation principles – reactive compensation at transmission and distribution level. (11)

COMPENSATORS AND REGULATORS: Shunt Compensator: Principle of operation - types - Variable Impedance type & switching converter type – STATCOM - configuration, characteristics and control-applications. Series compensator: Principles of operation- types - static series compensation using GCSC, TCSC and TSSC, SSSC – characteristics and control-applications. Voltage and phase angle regulators: Principles of operation-types-Steady state model and characteristics of a static voltage regulators and phase shifters- Thyristor controlled Voltage and phase angle regulators. Switching converter based voltage and phase angle regulators-applications. (13)

UNIFIED POWER FLOW CONTROLLER: Principles of operation – characteristics- independent active and reactive power flow control-applications. Comparison of UPFC with the controlled series compensators and phase shifters. Interline power flow controller - Principles of operation – characteristics. Coordinated control of FACTS Devices. Use of FACTS devices under deregulated environment. (11)

COORDINATION AND APPLICATION OF FACTS DEVICES: Modeling of FACTS devices, optimization of FACTS - Control strategies to improve system stability - Co-ordination of FACTS controllers. Application of FACTS Controllers: Sub-synchronous resonance, Damping oscillations, Transient stability and voltage stability. (10)

Total L: 45

REFERENCES:

1. Hingorani , L.Gyugyi, 'Understanding FACTS - Concepts and Technology of Flexible AC Transmission Systems', IEEE Press New York, 2011.
2. Mohan Mathur, Rajiv.K.Varma, "Thyristor Based FACTS Controllers for Electrical Transmission systems" John Wiley and Sons, 2011.
3. Padiyar K.R., 'FACTS Controllers in Transmission and Distribution Systems' New Age international Publishers, 2016.
4. Enrique Acha, Claudio R. Fuerte-Esquivel, Hugo Ambriz-Pérez, "FACTS: Modelling and Simulation in Power Networks", John Wiley, 2011.
5. Loi Lei Lai, 'Power System Restructuring and Deregulation', John Wiley & Sons Ltd. 2003.

21ED30 / 21EM33 POWER QUALITY MANAGEMENT

3 0 0 3

POWER QUALITY PROBLEMS: Definition of power quality – Power quality issues - Sources and Effects – International standards of Power quality and Electro Magnetic Compatibility (EMC), Computer Business Equipment Manufacturers Associations (CBEMA) curve - Voltage sags - Load influence on voltage sags – Stochastic assessment of voltage sags - Voltage Sags in Continuous Processes - Case Study – Interruptions – Types – Origin - Causes - Transients - Classification- Utility capacitor switching transients – Utility lightning protection – Transients from load switching - Impact on users. (12)

HARMONICS AND ELECTROMAGNETIC INTERFERENCE : Harmonics - Sources and effects of harmonic distortion – Standards – Impacts - Mitigation and control techniques – Devices for controlling harmonic distortion - Simulation using PSCAD.

Electromagnetic interference - Frequency classification - High-frequency interference - Electromagnetic interference – Susceptibility - EMI mitigation - Cable shielding to minimize Electromagnetic interference - Health concerns of electromagnetic interference. (11)

POWER QUALITY SOLUTIONS : Power quality monitoring considerations - Choosing monitoring locations - monitoring and diagnostic techniques for various power quality problems - modeling of power quality (harmonics and voltage sag) problems by mathematical simulation tools -power line disturbance analyzer –quality measurement equipment - harmonic / spectrum analyzer - flicker meters – disturbance analyzer. Applications of expert systems for power quality monitoring. (11)

POWER QUALITY CONDITIONERS: Shunt and series compensators - DSTATCOM - dynamic voltage restorer - unified power quality conditioners - Custom power devices and their applications in power system - Operating principles - Detailed modeling and analysis of DSTATCOM and DVR - Compensators to mitigate power quality related problems - Realization of DVR and DSTATCOM by using VSC. (11)

Total L: 45

REFERENCES:

1. Roger C. Dugan, Mark F. McGranaghan Surya Santoso and H. Wayne Beaty, "Electrical Power Systems Quality", Third edition, McGraw-Hill, New Delhi,2013.
2. Sankaran.C, "Power Quality", CRC Press, Baco Raton, 2017.
3. Math H J Bollen, "Understanding Power Quality Problems: Voltage Sags and Interruptions", Wiley India Pvt. Ltd., New Delhi, 2014.
4. J. Arrillaga, N.R. Watson and S. Chen, "Power System Quality Assessment", Wiley India Pvt. Ltd., New Delhi, 2011.
5. Arindam Ghosh and Gerard Ledwich, “Power quality enhancement using custom power devices”, Springer-Verlag, New York, 2012.

21ED31 / 21EM22 ADVANCED TOPICS IN POWER ELECTRONICS

3 0 0 3

INTRODUCTION TO SWITCHES: Advanced Silicon devices - Silicon HV thyristors, MCT, BRT & EST - Sic devices - diodes, thyristors, JFETs & IGBTs - Gallium nitrate devices - Diodes, MoSFETs (11)

ADVANCE CONVERTER TOPOLOGIES: Interleaved converters, Z-Source converters, Multi-level converters (cascaded H-bridge, diodeclamped, NPC, flying capacitor) Multi pulse PWM current source converters, Advanced drive control schemes.(12)

ADVANCES IN REACTIVE ELEMENTS: Advanced magnetic material, technology and design (powder ferrite, amorphous, planar designs) Advance capacitive designs (multilayer chip capacitors, double layers for storage, aluminum electrolytic) (11)

THERMAL SOLUTIONS AND EMI/EMC TECHNIQUES: Advanced thermal solutions (fan cooled, liquid cooled, heat pipes, hybrid techniques) EMC techniques (conducted, radiated emissions & susceptibility), System design for EMC. PCB design with EMI/EMC validations -case studies. (11)

Total L: 45

REFERENCES:

1. Andrzej M Trzynadlowski, ‘Introduction to Modern Power Electronics’, John Wiley and sons. Inc, New York, 3rd Edition, 2016.
2. Byungcho Choi, “Pulsewidth Modulated DC-to-DC Power Conversion Circuits, Dynamics, and Control Designs”, IEEE Press, Wiley, 2013.
3. B. Jayant Balinga, 'Advanced High Voltage Power Device Concepts', Springer New York 2011.
4. BIN Wu, 'High Power Converters and AC Drives', IEEE press Wiley Inter science, a John Wiley & Sons Inc publication 2006.
5. Wurth Electronics, 'Trilogy of Magnetics, Design guide for EMI filter design in SMPS & RF circuits', 4th edition, 2009.

21ED32 HVDC TRANSMISSION

3 0 0 3

BASICS OF HVDC TRANSMISSION : Introduction to HVDC transmission, Comparison between HVAC and HVDC systems - Economic, technical and reliability, limitations, Types of HVDC links - monopolar, bipolar and homopolar links, Components of HVDC transmission system.

ANALYSIS OF HVDC CONVERTERS: Analysis of HVDC Converters, Rectifier and Inverter operation of Graetz circuit without and with overlap. Output voltage waveforms and DC voltage in both rectifier and inverter operation, Equivalent circuit of HVDC link. (12)

CONTROL OF HVDC SYSTEMS: Basic means of HVDC system control, desired features, power reversal, Basic controllers - constant ignition angle, constant current and constant extinction/ advance angle control, power control, high level controllers. Converter malfunctioning - misfire, arc through, commutation failure. (11)

HARMONICS IN HVDC SYSTEM: Harmonics in HVDC system - Characteristic and uncharacteristic harmonics - Troubles due to harmonics – Harmonic filters - Active and passive filters - Reactive power control of converters, Protection issues in HVDC, over voltage and over current protection Voltage and current oscillations, DC reactor design, DC Circuit breakers. (11)

RECENT TRENDS IN HVDC TRANSMISSION: CSC based HVDC system, VSC based HVDC system – Multi-terminal HVDC systems and HVDC system applications in wind power generation, Interaction between AC and DC systems (11)

Total L : 45

REFERENCES:

1. Chan Ki Kim, Vijay K Sood, Gil Soo Jang, "HVDC transmission: power conversionapplications in power systems", John Wiley & Sons, 2009.
2. Padiyar, K.R., 'HVDC transmission systems', Wiley Eastern Ltd., 2010.
3. Kamakshaiah, S and Kamaraju, V, 'HVDC Transmission', 1st Edition, Tata McGraw Hill Education, Newdelhi 2011.
4. Arrillaga, Jos, Yong He Liu, and Neville R. Watson, "Flexible power transmission: the HVDC options", John Wiley & Sons, 2007.
5. Vijay K. Sood, 'HVDC and FACTS Controllers', Kluwer Academic Publishers, New York, 2004.

21ED33 DESIGN OF SOLAR PHOTOVOLTAIC SYSTEMS

3 0 0 3

FUNDAMENTALS OF SOLAR PHOTOVOLTAIC TECHNOLOGY: Historical review- Basic approaches and objectives - Phenomena of light and energy- Energy from the sun - Photovoltaic(PV) cell characteristics - Model of PV cell - Datasheet study.
Solar photovoltaic modules: Design structure of PV modules – Series and parallel connection of cells - Identical cells in series- Non-identical cells in series - Protecting cells in series - Interconnecting modules in series - Identical cells in parallel-Non-identical cells in parallel - Protecting cells in parallel – I-V and power curve of PV modules - Effect of temperature. (12)

SOLAR RADIATION: Insolation and irradiance- Insolation variation with time of day - Solar radiation outside the earth's atmosphere - Solar radiation at the earth's surface – Solar radiation data - Solar radiation geometry - Effect of solar irradiation - Energy on a horizontal flat surfaces - Energy on a tilted flat surfaces – Energy with atmospheric effects- PV System Emulation. (11)

SIZING OF PV: Batteries - Capacity – Factors affecting battery performance - Choice of battery – Battery charging and discharging methods – Battery size. Charge controllers - Types of charge controllers - Maximum Power Point Tracking (MPPT) - Algorithms of MPPT- Impedance control methods, Reference cell, Sampling method, Power slope methods, Hill climbing method – PV module simulation. (11)

PHOTOVOLTAIC SYSTEM DESIGN AND APPLICATIONS: Classifications - Standalone, grid connected and hybrid PV systems - configurations - working principle - Application examples.
Economic Analysis : Payback period - Life cycle costing – Time value of Money - present worth factor -Life cycle cost with example. (11)

Total L : 45

REFERENCES:

1. Chetan Singh Solanki, "Solar Photovoltaics: Fundamental, Technologies and Applications", PHI Learning Pvt. Ltd, New Delhi, 2015.
2. Suhas P Sukhatme and J K Nayak, "Solar Energy : Principles of Thermal Collection and Storage",. Tata Mc-Graw Hill, Edition 3, New Delhi, 2014
3. Rao S, Parulekar B B, "Energy Technology : Nonconventional, Renewable and Conventional", Khanna Publisher, New Delhi, 2013.
4. Parimita Mohanty, Tariq Muneer, Mohan Kolhe, "Solar Photovoltaic System Applications: A Guidebook for Off-Grid Electrification", Springer, 2015.
5. S. Sumathi, L. Ashok Kumar, P. Surekha, "Solar PV and Wind Energy Conversion Systems: An Introduction to Theory, Modeling with MATLAB/SIMULINK, and the Role of Soft Computing Techniques", Springer, 2015.

21ED34 / 21EA32 / 21EE42 / 21EM32 OPTIMIZATION TECHNIQUES

3 0 0 3

LINEAR PROGRAMMING: Statement of Optimization problems, Principles of single and multi-objective optimization, Graphical method, Simplex method, Revised simplex method, Two phase simplex method, Duality in linear programming, Sensitivity analysis. (12)

NON-LINEAR PROGRAMMING (UNCONSTRAINED OPTIMIZATION): Direct search methods - Univariate method, Pattern search method, Simplex method, Descent methods - Steepest Descent method, Conjugate gradient method, Quasi Newton method. (11)

NON-LINEAR PROGRAMMING (CONSTRAINED OPTIMIZATION): Direct methods - The Complex method, Zoutendijk's Method of Feasible Directions, Rosen's Gradient Projection Method , Indirect method - Transformation Techniques, Basic Approach of the Penalty Function Method, Interior Penalty Function Method, Exterior Penalty Function Method. (11)

DYNAMIC PROGRAMMING: Multistage decision process, Suboptimization and Principle of Optimality, Computational procedure, Final value problem to initial value problem, Linear Programming as a Case of Dynamic Programming, Continuous dynamic programming (11)

Total L:45

REFERENCES:

1. Hamdy A Taha, “Operations Research: An Introduction”, Pearson Education, New Delhi, 2012.
2. Singaresu S Rao, “Engineering Optimization: Theory and Practice”, New Age International, New Delhi, 2011.
3. David.G.Luenberger, Yinyu Ye, "Linear and Nonlinear Programming", Springer, Newyork,2015.
4. Gupta C B, “Optimization Techniques in Operations Research”, I K International, New Delhi, 2012.
5. Sharma J K, “Operations Research: Theory and Applications”, Macmillan Company, New Delhi, 2013.

21ED35 PULSE WIDTH MODULATED POWER ELECTRONIC CONVERTERS

3 0 0 3

PURPOSE OF PWM: Review of Fourier series, fundamental and harmonic voltages; machine model for harmonic voltages; undesirable effects of harmonic voltages – line current distortion, increased losses, pulsating torque in motor drives; control of fundamental voltage; mitigation of harmonics and their adverse effects (11)

PWM TECHNIQUES: Square wave operation of voltage source inverter, PWM with a few switching angles per quarter cycle, equal voltage contours, selective harmonic elimination, THD optimized PWM, off-line PWM, Triangle-comparison based PWM-Average pole voltages, sinusoidal modulation, third harmonic injection, continuous PWM, bus-clamping or discontinuous PWM, Space vector based PWM -bus-clamping PWM. (12)

ANALYSIS OF PWM CONVERTERS: Analysis of line current ripple, Analysis of dc link current - Analysis of torque ripple, Inverter loss, Effect of inverter dead-time effect. (11)

OVERMODULATION & PWM FOR MULTILEVEL INVERTER: Per-phase and space vector approaches to over modulation, average voltages in a synchronously revolving d-q reference frame, low-frequency harmonic distortion. Extensions of sine-triangle PWM to multilevel inverters, voltage space vectors, space vector based PWM, analysis of line current ripple and torque ripple. (11)

Total: L: 45

REFERENCES:

1. Ned Mohan, Tore M. Undeland and William P. Robbins., "Power Electronics: Converters, Applications and Design", John Wiley and Sons, 3rd Edition, 2003.
2. Choi, Byungcho., “Pulsewidth modulated DC-to-DC power conversion: circuits, dynamics, and control designs”, John Wiley & Sons, 2013.
3. Holmes, D. Grahame, and Thomas A. Lipo., “Pulse width modulation for power converters: principles and practice”, Vol. 18, John Wiley & Sons, 2003.
4. Andrzej M Trzynadlowski, ‘Introduction to Modern Power Electronics’, John Wiley and sons. Inc, New York, 3rd Edition, 2016.
5. Zhong, Qing-Chang, and Tomas Hornik,“Control of power inverters in renewable energy and smart grid integration”, Vol. 97, John Wiley & Sons, 2012.

21ED36 / 21EE44 / 21EM36 SMART GRID TECHNOLOGIES

3 0 0 3

SMART GRID ARCHITECTURE AND COMPONENTS: Need for Smart Grid – Functions – Opportunities – Benefits and challenges, Difference between conventional & Smart Grid, Concept of Robust & Self-Healing Grid, Smart Grid Architecture - Models - Standards, and Road map for Smart Grid in India. WIDE AREA MONITORING SYSTEM: Fundamentals of Synchrophasor Technology. Structure and functions of Phasor Measuring Unit (PMU) and Phasor Data Concentrator (PDC). Operational experience and Blackout analysis using PMU - Case study on Blackout on Indian Grid. (11)

MICROGRIDS AND DISTRIBUTED ENERGY RESOURCES: Distributed Generation – Concept and topologies, Renewable Energy in Distributed Generation - Grid integration of DGs - IEEE 1547 Standard – Issues in Grid Interface of DGs – Inverter and rotating machine based DGs. Power Quality issues of Grid connected Renewable Energy Sources - Web based Power Quality monitoring and Audit. MICRO GRIDS: Introduction to Micro grids – types – Structure and configuration of Microgrids – AC and DC Micro grids – Power Electronic Interfaces – Energy Management and Protection Control Strategies of a Micro grid - Case Studies. (12)

SMART METERING AND DISTRIBUTION MANAGEMENT SYSTEM (DMS): Volt / VAR control – Fault Detection, Isolation and Service Restoration, Network Reconfiguration, Outage management System, Effect of Plug in Hybrid Electric Vehicles, V2G AND G2V topologies. Energy Storage for Smart Grids: Electric and Non-Electric Storage Systems. Introduction to Smart Meters – Advanced Metering infrastructure (AMI), AMI protocols – Standards, Demand response programs and Demand pricing. (11)

COMMUNICATION NETWORKS AND CYBER SECURITY FOR SMART GRID: Communication Architecture for Smart Grids, Home Area Network (HAN): Zigbee Smart Energy Profile, IEEE 802.11, Neighbourhood Area Network (NAN) : RF Mesh, Wireless Star, Radio over Power-Lines (BPL/PLC), Wide Area Network (WAN) : OFC, Cellular Networks, Wi-Max and Wireless Sensor Networks. Smart Grid Cyber Security Requirements - Attacks against Cyber-Physical Systems - Mapping of Cyber Attacks to Control Actions and System Impact. Smart Grid Cyber Security Potential Threats, Vulnerabilities and Risks in Advanced Metering Infrastructure. (11)

Total L : 45

REFERENCES:

1. Stuart Borlase, “Smart Grid: Infrastructure, Technology and Solutions”, CRC Press, 2012.
2. Janaka Ekanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu and Akihiko Yokoyama, “Smart Grid: Technology and Applications”, Wiley, 2012.
3. Ali Keyhani, “Design of Smart Power Grid Renewable Energy Systems”, Wiley, 2016
4. N. Jenkins, Nicholas Jenkins, “Distributed Generation” IET Press, 2010.
5. Clark W. Gellings, “The Smart Grid: Enabling Energy Efficiency and Demand Response”, CRC Press , 2009

21ED37 / 21EM37 DISTRIBUTED GENERATION AND MICROGRIDS

3 0 0 3

DISTRIBUTED GENERATION : Energy Sources and their availability -Trends in Energy Consumption, Conventional and Non-conventional Energy Sources – Review of Solar Photovoltaic systems – Wind Energy Systems – Fuel Cells , Energy storage systems: Batteries – ultra capacitors – fly wheels – captive power plants. Distributed Generation – Concept and topologies, Renewable Energy in Distributed Generation. IEEE 1547 Standard for Interconnecting Distributed Generation to Electric Power Systems – DG Installations – Siting and sizing of DGs – optimal placement – Regulatory issues. (11)

ISSUES IN GRID INTEGRATION OF DISTRIBUTED ENERGY RESOURCES : Basic requirements of Grid Interconnections – operational Parameters – Voltage, Frequency and THD limits – Grid Interfaces – Inverter based DGs and rotary machines based DGs – Reliability, Stability and Power Quality issues on Grid Integration – Impact of DGs on Protective Relaying and islanding issues in existing distribution Grid. (11)

MICRO GRIDS: Introduction to Micro grids – types – Structure and configuration of Micro grids – AC and DC Micro grids – Power Electronic Interfaces for Micro grids – Energy Management and Protection Control Strategies of a Microgrid - Case Studies. (11)

CONTROL AND OPERATION OF MICRO GRID: Modes of operation and control of microgrid: grid connected and islanded mode, Active and reactive power control, protection issues, anti-islanding schemes: passive, active and communication based techniques, microgrid communication infrastructure, Power quality issues in micro grids, regulatory standards, Microgrid economics, Introduction to smart micro grids. (12)

Total L : 45

REFERENCES:

1. Gregory W. Massey, “Essentials of Distributed Generation Systems”, Jones & Bartlett Publishers, 2011.
2. Math H. Bollen, “Integration of Distributed Generation in the Power System”, John Wiley & Sons, 2011.
3. N. Jenkins, Nicholas Jenkins, “Distributed Generation” IET Press, 2010.
4. S. Chowdhury, P. Crossley, “Microgrids and Active Distribution Networks”, IET Press, 2010.
5. Ali Keyhani, “Design of Smart Power Grid Renewable Energy Systems”, John Wiley & Sons, 2011.

21ED38 / 21EM38 ELECTRIC VEHICLES

3 0 0 3

VEHICLE FUNDAMENTALS: Vehicle movement, Vehicle resistance, Dynamic equation, Power train tractive effort and vehicle speed, Vehicle power plant and transmission characteristics, Vehicle performance, Operating fuel economy, Braking performance. (11)

ELECTRIC AND HYBRID ELECTRIC VEHICLES: History, Environmental impact, Configurations of electric vehicles, Performance of electric vehicles, Tractive effort in normal driving, Energy consumption, Concept and architecture of hybrid electric drive trains. (11)

ELECTRIC COMPONENTS IN HYBRID AND ELECTRIC VEHICLES: Electric Drives in HEV/EVs, Classification and Characteristics, configuration and Control of DC Motor drives: Brushed and Brushless, Induction Motor drives, Switched Reluctance Motor drives for HEV/EVs applications, Drive System efficiency, Performance matching of Electric Machine and the Internal Combustion Engine (ICE), Sizing the propulsion motor, sizing of power electronic devices and Energy Storage systems. (12)

ENERGY MANAGEMENT STRATEGIES: Electrochemical batteries: Overview of Batteries-Battery Parameters-Lead acid batteries-Lithium ion batteries-Metal air batteries-Battery Charging, Ultracapacitors, Ultrahigh-speed flywheels, Hybrid sources, Fuel Cell Technologies. (11)

Total L: 45

REFERENCES:

1. Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay and Ali Emadi, “Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design”, CRC Press, 2009.
2. Iqbal Husain, “Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2011.
3. James Larminie and John Loury, “Electric Vehicle Technology-Explained”, John Wiley & Sons Ltd., 2003.
4. Aulice Scibioh M. and Viswanathan B., “Fuel Cells – Principles and Applications”, University Press, India, 2006.
5. NPTEL Lecture notes on 'Introduction to Hybrid and Electric Vehicles', 2013.

21ED39 POWER CONVERTERS AND CHARCHING TECHNOLOGIES FOR ELECTRIC VEHICLES

3 0 0 3

VEHICLE ELECTRIFICATION: Introduction and definition, energy management in electric vehicles, Comparison of battery SOC profile for various EV modes of control, intelligent energy management of EVs with environment; EVs charging options and infrastructure; Energy, Economic, and Environmental Considerations; Impacts of EV Charging on the Power Grid – general considerations, effects of EV charging on battery lifetime, generation and load profile, distribution networks; The Role of Smart Charging Technologies and Applications (11)

POWER CONVERTRS FOR EV CHARGING: Bidirectional converter topologies for plug in vehicles, dual active converters for vehicle to grid, Converters for regenerative braking, Converters for ultra capacitor applications, converters for multiphase integrated onboard charger (11)

EV BATTERIES: Types of Battery, Vehicle requirements: energy and power requirements, battery design: cell selection, battery components, reliability and safety, battery control and management: battery management system, state functions (11)

EV CHARGING TECHNOLOGIES: Charging and charge completion of a single battery, temperature compensation during charging, charging technologies; Fast charging – fast charging process and strategies, fast charger configurations; Inductive charging; Battery discharging – discharge capacity behaviour, discharge characteristics of a single battery, discharge of an EV battery pack, cold-weather impact on battery discharge (12)

Total L: 45

REFERENCES:

1. Ottorino Veneri, “Technologies and Applications for Smart Charging of Electric and Plug-in Hybrid Vehicles”, Springer, 2017.
2. L. Ashok Kumar, S. Albert Alexander, "Power Converters for Electric Vehicles", CRC Press, 2021.
3. Helena Berg, "Batteries for Electric Vehicles" Cambridge University Press, 2015.
4. Williamson, Sheldon S.,“Energy management strategies for electric and plug-in hybrid electric vehicles”,New York, NY: Springer, 2013.
5. Rajakaruna, Sumedha, Farhad Shahnia, and Arindam Ghosh, eds.,“Plug in electric vehicles in smart grids: charging strategies”, Springer, 2014.

21ED40 INTEGRATED CIRCUITS AND DEVICES FOR POWER ELECTRONICS

3 0 0 3

INTEGRATED CIRCUITS: Introduction to Op-Amp, Linear and Non-Linear applications. Pulse width modulation for power converters- Trailing edge, leading edge, and double edge carrier wave generation -Practical design problems.

MIXED-SIGNAL DESIGN: Introduction to SystemVerilog - Inverters, Gates, Buffer Design - Switched Mode RF Power Amplifiers, PWM pulse generation for RF power amplifiers (12)

PLL AND SENSOR INTERFACES FOR POWER CONVERTER: Phase locked loop (PLL) and synchronization Methods for Grid interfaced converters - Practical circuit using PLL IC. 555 Timer based application circuits- Design of Signal Gain for AC/DC Voltage and current sensors (11)

DC-DC CONVERTER TOPOLOGIES: Switched-inductor, switched-capacitor, and hybrid converters- Integrated passives and design: integrated inductors and integrated capacitors High voltage Isolation Interfaces for power converters-Opto-isolator – biasing circuits with 1:N isolation transformer. (11)

POWER MANAGEMENT ICS: PMIC Design procedure-Current Sense Circuits- Level Shifter Circuits- ESD - Protection and Timing Consideration (11)

Total L : 45

REFERENCES:

1. Robert F. Coughlin and Frederick F. Driscoll, "Operational Amplifiers and Linear IntegratedCircuits", PHI Learning Private Limited, Sixth Edition, 2015.
2. Bob Dobkin, Jim Williams, “Analog Circuit Design: A Tutorial Guide to Applications andSolutions”, Elsevier Inc, First Edition, 2011.
3. P. Allen, D. Holberg, Fundamentals of Power Electronics, Second Edition ,Kluwer Academic Publishers, 2001
4. Rabaey, Jan M., Anantha P. Chandrakasan, and Borivoje Nikolić.,“Digital integrated circuits: a design perspective”, Vol. 7, NJ: Pearson education, 2003.
5. Digital Flow: S. Palnitkar, Verilog HDL: A Guide to Digital Design and Synthesis, Second Edition, Sun Microsystems Press / Prentice Hall, 2003.

21ED41 INDUSTRIAL DRIVES FOR AUTOMATION

3 0 0 3

INTRODUCTION: Construction and Principle of operation of PMSM and SynRM – AC drive Hardware Blocks – Control Blocks– Automatic Motor Adaptation – Parameterization of Drives (Local and Remote). (11)

CONFIGURATIONS OF DIFFERENT I/O CONTROL: Digital Input and output – Analog Input and output Control-word access – Motion control - Sequential Logic Control (SLC) - Parameterization for different communication protocol: RS 485 – MODBUS PROFIBUS. (11)

CONFIGURATION FOR DIFFERENT APPLICATIONS: AQUA – HVAC – Automation – Master/ Slave control. (12)

CONTROL OF DRIVES: Performance characterization of PMSM and SynRM - Conveyor control – Cascaded Pump Control Synchronization of Drives with Master Slave Control. (11)

Total L: 45

REFERENCES:

1. Boldea, Ion, and Syed A. Nasar, “Electric drives”, CRC press, 2016.
2. Krishnan, Ramu “Permanent magnet synchronous and brushless DC motor drives”, CRC press, 2017.
3. Nasar, SyedA. “Vector control of AC drives”, Routledge, 2017.
4. Programming Guide for FC Drives by Danfoss Industries pvt. Ltd.
5. Monograph prepared by PSG-Danfoss CoE for Climate and Energy

OPEN ELECTIVES

21ED91 BUSINESS ANALYTICS

21EA91 vide Applied Electronics

21ED92 ELECTRONIC WASTE MANAGEMENT

21EA92 vide Applied Electronics

21ED93 INDUSTRIAL SAFETY AND STANDARDS

21EA93 vide Applied Electronics

21ED94 INNOVATION AND PRODUCT DEVELOPMENT

21EA94 vide Applied Electronics