

M. TECH - POWER AND ENERGY ENGINEERING
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

The restructuring and deregulation of electric utilities together with recent progress in Smart 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. The advancement in Power & Energy with the vision of redefining the Conventional Power System as an Intelligent Power Grid with a blend of the latest technologies like Smart Sensing, Cyber Physical System and ICT coupled with Renewable Energy Sources, Electric Vehicle, and Energy Storage etc. will be the key factors to a sustainable world for future generations.

M. Tech. program in Power and Energy is intended to explore the above mentioned challenges and also to initiate intense research activities. The structure of lab oriented courses will enable the students to have an insight into the real time scenarios and can build a thorough understanding of the systems as a whole. The Power and Energy courses emphasis on the various streams like Power System, Sustainable and Renewable Energy, Computational and Communication Technology Applications, Power Electronics and Control, Smart Technology and Embedded Systems. This programs aims to make students employable in various sectors of Power & Energy, Communication, Smart grid, Electric Transport, Petroleum Industry, Energy Management and Conservations etc. and to impart interest in carrying out high end research activities in these areas.

CURRICULUM
FIRST SEMESTER

Course Code	Type	Course	L-T-P	Credit
18MA608	FC	Software Based Numerical Computation Methods	3-0-1	4
18PR621	SC	Power System Planning, Operation and Control	2-0-2	4
18PR622	SC	Sustainable and Renewable Energy Technology	2-0-2	4
18PR601	FC	Power Electronics for Renewable Energy Technologies	2-0-2	4
18PR602	FC	Computational Intelligence for Power Applications	2-0-1	3
18PR623	SC	Applied Digital Signal Processing	2-0-2	4
18HU601	HU	Amrita Values Program*		P/F
18HU602	HU	Career Competency I*		P/F
Credits				23

*Non Credit Course

SECOND SEMESTER

Course Code	Type	Course	L-T-P	Credit
18PR624	SC	Restructured Power System Optimisation	3-0-1	4
18PR625	SC	Power Quality and FACTS	3-0-1	4
18PR626	SC	Smart Grid	3-0-1	4
	E	Elective I	2-0-1	3
	E	Elective II	2-0-1	3
18PR603	FC	Application Development Lab.	0-0-3	2
18RM600	SC	Research Methodology	2-0-0	2
18HU603	HU	Career Competency II	0 0 2	1
Credits				23

THIRD SEMESTER

Course Code	Type	Course	L-T-P	Credit
18PR798	P	Dissertation		8

FOURTH SEMESTER

Course Code	Type	Course	L-T-P	Credit
18PR799	P	Dissertation		12
Total Credits				66

ELECTIVES

Subjects includes areas from power System, Sustainable and Renewable Energy, Computational and Communication Technology, Power electronics and Control, Smart Technology and Embedded Systems.

Course Code	Type	Course	L-T-P	Credit
18PR701	E	Power Plant Instrumentation	2-0-1	3
18PR702	E	Mathematical Modelling of Energy Systems	2-0-1	3
18PR703	E	Energy Conservation and Management	2-0-1	3
18PR704	E	Energy Storage Technology	2-0-1	3
18PR705	E	Electric Drives and Control	2-0-1	3
18PR706	E	Logic and Distributed Control Systems	2-0-1	3
18PR707	E	Control System Design	2-0-1	3
18PR708	E	Machine learning and Multi Agent Systems for Power Engineering	2-0-1	3
18PR709	E	Smart Electrical Networks and Intelligent Communication Systems	2-0-1	3
18PR710	E	Solar Energy Utilisation	2-0-1	3
18PR711	E	Wind Energy Conversion Systems	2-0-1	3
18PR712	E	Bio- Energy Conversion	2-0-1	3
18PR713	E	Advanced Digital Signal Processors and Applications	2-0-1	3
18PR714	E	Electric Vehicle Technology	2-0-1	3
18PR715	E	Cyber Physical Systems	2-0-1	3
18PR716	E	ICT Enabled Power System Protection	2-0-1	3

LIST OF COURSES

FOUNDATION CORE

Course Code	Type	Course	L-T-P	Credit
18MA608	FC	Software Based Numerical Computation Methods	3-0-1	4
18PR601	FC	Power Electronics for Renewable Energy Technologies	2-0-2	4
18PR602	FC	Computational Intelligence for Power Applications	2-0-1	3
18PR603	FC	Application Development Laboratory	0-0-3	2

SUBJECT CORE

Course Code	Type	Course	L-T-P	Credit
18PR621	SC	Power System Planning, Operation and Control	2-0-2	4
18PR622	SC	Sustainable and Renewable Energy	2-0-2	4

		Technology		
18PR623	SC	Applied Digital Signal Processing	2-0-2	4
18PR624	SC	Restructured Power System Optimisation	3-0-1	4
18PR625	SC	Smart Grid	3-0-1	4
18PR626	SC	Power Quality and FACTS	3-0-1	4

18MA608 SOFTWARE BASED NUMERICAL COMPUTATION METHODS 3-0-1-4

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, LU decomposition and partial pivoting, Gauss-Jordan method and iterative methods, inverse of a matrix by Gauss Jordan method, Eigen value of a matrix by power method, Simulation/case study in short circuit analysis. 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, Simulation/case study in transient stability analysis, midterm stability analysis, etc. Linear programming: Formulation, graphical and simplex methods, Big-M method. Regression & interpolation: linear least squares regression, functional and nonlinear regression, Simulation/case study in state estimation, optimal power flow, etc. Unconstrained one dimensional optimization techniques: Necessary and sufficient conditions. Unrestricted search methods: quadratic interpolation methods, cubic interpolation and direct root methods. Unconstrained n- dimensional optimization techniques: Direct search methods, random search, descent methods, steepest descent, conjugate gradient, Simulation. Constrained optimization techniques: necessary and sufficient conditions, equality and inequality constraints, Kuhn-Tucker conditions, penalty function method, Simulation/Case study in economic operation of power systems. Dynamic programming, principle of optimality, recursive equation approach, application to shortest route, cargo-loading, allocation and production schedule problems, Simulation/case study in transmission system expansion. Practice session: Simulation and coding of different computational methods as mentioned above.

TEXT BOOKS/ REFERENCES:

1. Fox R. L., "Optimization Methods for Engineering Design", Addison Wesley, 1971.
2. S. S. Rao, "Engineering Optimisation Theory and Practice", John Wiley and Sons, 2009.
3. Taha H. A., "Operations Research – An Introduction", Prentice Hall of India, Eighth Edition, 2008.
4. Gerald C. F. and Wheatley P. O., "Applied Numerical Analysis", Sixth Edition, Pearson Education Asia, New Delhi, 2002.
5. Fausett L. V. "Applied Numerical Analysis using MATLAB" Pearson Education Second Edition..
6. S.A. Soman, S.A. Khaparde, Shubha Pandit, " Computational Methods for Large Sparse Power Systems Analysis: An Object Oriented Approach Power Electronics and PowerSystems", Springer Science & Business Media, 2012.
7. Mariesa L. Crow, "Computational Methods for Electric Power Systems", CRC Press, 2015.

18PR621 POWER SYSTEM PLANNING, OPERATION AND CONTROL 2-0-2-4

Introduction to planning operation and control. Objectives of planning: Long and short term planning, load forecasting, advanced methodologies. Economic operation: Review of thermal units, 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. Hard limits and slack variables. hydro-thermal coordination, long range and short range scheduling, scheduling problems, scheduling energy, short-term hydrothermal scheduling problem, pumped storage hydro plants, pumped storage hydro scheduling λ - γ iteration, fast scheduling techniques. 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, synchronised measurements-PMU. Power system security: system monitoring, contingency analysis, security constrained optimal power flow, factors affecting power system security, advanced security monitoring. Transient stability analysis (multi machine system), small signal stability and power system oscillations, voltage stability, direct stability methods, power system stabilizers. Load frequency control: basic concepts of governor mechanism, 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. SCADA and decision-making tools in control centers, advanced controller techniques. Simulation oriented case studies.

TEXT BOOKS/ REFERENCES:

1. *Allen J. Wood and Wollenberg B.F., "Power Generation Operation and Control", Wiley 2nd Edition, 2011.*
2. *A. Monticelli, "Electric Power System State Estimation", Proc. IEEE, Vol. 88, No.2, 2000.*
3. *Olle I. Elgerd, "Electric Energy and System Theory – An Introduction", Tata McGraw-Hill Publishing Company Limited, New Delhi, 2013.*
4. *N. V. Ramana, "Power System Operation and Control", Pearson, 2012.*
5. *Hassan Bevarani, Masayuki Watanabe and Yasunori Mitani, "Power System Monitoring and Control", Wiley-IEEE Press, 2014.*
6. *Prabha Kundur, "Power System Stability and Control", McGraw-Hill Education, 2011.*
7. *Sullivan, R.L., "Power System Planning", Heber Hill, 1997.*
8. *K.R. Padiyar, "Power System Dynamics: Stability and Control", John Wiley & Sons, 2008.*
9. *Abhijit Chakrabarti, Sunitha Halder., "Power System Analysis Operation and Control", Prentice-Hall of India , 2006.*

18PR622 SUSTAINABLE AND RENEWABLE ENERGY TECHNOLOGY 2-0-2-4

Challenges of Energy Sustainability. Future Energy Systems: Clean/Green Energy Technologies. International agreements/conventions on Energy and Sustainability: United Nations Framework Convention on Climate Change (UNFCCC) sustainable development. Renewable Energy Technologies: Renewable energy utilization in ancient times, Solar energy: Solar radiation measurements, Effects of changes in tilt angle, Sun Tracking, PV cell

: Principle, types, PV Module and Array, Modelling of PV cell, Effects of shaded and faulty cell, Maximum power tracking, Charge Controllers, MPPT Algorithms, Stand Alone PV System, Grid Connected PV System, Hybrid Systems. Wind energy: Atmospheric circulations, Wind monitoring and resource assessment, modelling, Types and characteristics of wind turbines, thrust and torque, power coefficient, thrust coefficient, axial interference factor, Pitch and stall regulation, power curve, energy calculation, Principle of operation, types, configurations: WT-IG, WT-DWIG, WTDOIG, WT-PMG and WTVSIG. Small WEGs - standalone/grid connected applications. Other Renewable Energy Technologies: Biomass-Gasifiers, Small hydro, wave, tidal, ocean thermal, geothermal. Energy storage: Principles of Battery, Super capacitor, Fuel cells, its operation, types, applications. State of the Art in Power & Energy industry and R&D, Various Hardware and software experiments on solar PV cell and Module, standalone system design and development, MPPT tracking and control algorithm, Wind energy systems.

TEXT BOOKS/ REFERENCES:

1. *Energy and the Challenge of Sustainability, World Energy assessment, UNDP, N York, 2000.*
2. *Thamas B Johansson et al, "Renewable Energy Sources for fuel and electricity", Earthscan Publishers, London, 1993.*
3. *J W Twidell and A D Weir, "Renewable Energy Resources", ELBS, 1998.*
4. *N K Bansal, M Kleemann and M Mellis, "Renewable Energy Resources and conversion Technology", Tata McGraw Hill, 1990.*
5. *G N Tiwari, M K Ghosal, "Fundamentals of Renewable Energy Sources", Narosa Publishing House.*
6. *Kastha D, Banerji S and Bhadra S N, " Wind Electrical Systems", Oxford University Press, New Delhi, 1998.*
7. *Tony Burton, David Sharpe, Nick Jemkins and Ervin Bossanyi., "Wind Energy Hand Book", John Wiley & Sons, 2004.*
8. *Chetan S. Solanki, "Solar Photovoltaics: Fundamentals, Technologies and Applications", Second Edition, PHI Publications, 2011.*

18PR625

POWER QUALITY AND FACTS

3-0-1-4

Review of power quality issues, definitions and standards, causes and effects of power quality issues, measurements. Harmonic studies: Fourier analysis, FFT Analysis, HVDC systems and harmonics in HVDC Systems. Improvement techniques: Conventional compensators, Passive (RLC) compensators: shunt/series, Active (synchronous condensers). FACTS compensators: Shunt compensators: Passive/ variable z type Active/switched converter type. Series compensators: Passive/ variable z type. Active/switched converter type. Hybrid compensators. Harmonic Filters: Passive filters, tuned filters, design problems, Active filters-shunt, series, hybrid. Applications and Design problems. Estimation of rate/cost reduction due to hybrid filters. Active filter control schemes/algorithms: Time-domain and Frequency-domain algorithms, AI based control algorithms, analog/digital implementation. Case studies. Review of improved power quality converters and applications. Custom power parks concept: Custom power devices and applications. Lab Experiments: Simulation and Hardware experiments in Conventional/FACTS/Harmonic compensators.

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. Bhim Singh, Ambrish Chandra and Kamal Al-Haddad, "Power Quality: Problems and mitigation Techniques", Wiley 2015.
4. Enrique Acha and Manuel Madrigal,"Power Systems Harmonics-Computer Modeling and Analysis", John Wiley and Sons Ltd., 2001.
5. George J. Wakileh, "Power Systems Harmonics-Fundamentals, Analysis and Filter Design", Springer-Verlag, New York, 2001.
6. Selected Publications on Power Quality Improvement.
7. Ewald F. Fuchs and Mohammad A. S. Masoum, "Power Quality in Power Systems and Electrical Machines", 1st edition, Elsevier Academic Press, San Diego, USA, 2008, ISBN: 978-0-12-369536-9.
8. Roger C. Dugan, Mark F. McGranaghan, Surya Santoso and H. Wayne Beaty, "Electrical Power Systems Quality", 2nd edition, McGraw-Hill, New York, USA, 2002, ISBN-10:0-07-138622-X.
9. Jos Arrillaga, Bruce C. Smith, Neville R. Watson and Alan R. Wood, "Power System Harmonic Analysis", 1st edition, Jonh Wiley & Sons, Chichester, UK, 1997, ISBN-10:0-471-97548-6.
10. J. Schlabbach, D. Blume and T. Stephanblome, "Voltage Quality in Electrical Power Systems", 1st edition, The Institution of Engineering and Technology, London, UK/1999, ISBN-10:0-85296-975-9, ISBN13:978-0-85296-975-5.
11. Alexander Kushko and Marc T. Thompson, "Power Quality in Electrical Systems", 1st edition, McGraw-Hill, New York, USA, 2007, ISBN-10:0-07-147075-1, ISBN-13:978-0-07-147075-9.

18PR602 COMPUTATIONAL INTELLIGENCE FOR POWER APPLICATIONS

2-0-1-3

Introduction to Computational Intelligence, Intelligence machines, Computational intelligence paradigms, Rule-Based Expert Systems and Fuzzy Expert Systems, Rule-based expert systems, Uncertainty management, Fuzzy sets and operations of fuzzy sets, Fuzzy rules and fuzzy inference, Fuzzy expert systems, Case study: fuzzy logic controller for washing machines, Artificial Neural Networks, Fundamental neuro computing concepts: artificial neurons, activation functions, neural network architectures, learning rules. Supervised learning neural networks: multi-layer feed forward neural networks, simple recurrent neural networks, time-delay neural networks, supervised learning algorithms, Unsupervised learning neural networks: self-organizing feature maps, Radial basis function networks, Deep neural networks and learning algorithms. Case study: anomaly detection, Evolutionary computation, Chromosomes, fitness functions, and selection mechanisms. Genetic algorithms: crossover and mutation, Genetic programming, Evolution strategies, probabilistic reasoning, Hybrid Intelligent Systems, Neural expert systems, Neuro-fuzzy systems, Evolutionary neural networks, Case study and Simulation of artificial intelligence, fuzzy evolutionary algorithms in power system applications.

TEXT BOOKS/ REFERENCES:

1. Timothy J Ross, "Fuzzy Logic with Engineering Applications", Wiley India Private Limited, 2010.
2. Laurene Fausett, "Fundamentals of neural Network, Architecture, Algorithms, and Applications", Pearson Education, 2002.
3. John Yen and Reza Langari, "Fuzzy logic, Intelligence control and Information", Pearson Education, 2003.
4. M. Negnevitsky, "Artificial Intelligence: A Guide to Intelligent Systems", 3rd Edition, Pearson/Addison Wesley, 2011.
5. A.P. Engelbrecht, "Computational Intelligence: An Introduction", 2nd Edition,
6. John Wiley & Sons, 2012 Gerald C. F. and Wheatley P. O, "Applied Numerical Analysis", Sixth Edition, Pearson Education Asia, New Delhi, 2002.
7. S. Russell and P. Norvig. "Artificial Intelligence – A Modern Approach", Prentice Hall, 2010
8. H.K. Lam, S.S.H. Ling, and H.T. Nguyen, "Computational Intelligence and Its Applications: Evolutionary Computation, Fuzzy Logic, Neural Network and Support Vector Machine", Imperial College Press, 2011
9. N. Baba and L.C. Jain, "Computational Intelligence in Games", Heidelberg; New York: Physica-Verlag, 2001

18PR623

APPLIED DIGITAL SIGNAL PROCESSING

2-0-2-4

Overview of available micro-controllers, Introduction to Embedded Systems, Digital Signal Controllers, Digital Signal processors available in the market. Modified Harvard Architecture based microcontroller: Introduction, file registers, memory organization, interrupts, electrical characteristics, peripherals: Ports, Timer, ADC, USART, PWM Channels. Signal generation: PWM, SPWM and servo signals. Filtering algorithms: FIR filters, IIR filters, Control Algorithms: P, PI, PID controllers, Fourier Transforms: DFT, FFT, DCT algorithms. Lab Practice: Interfacing power electronic switches, voltage and current measurement techniques, digital ammeter and voltmeter, PWM based power converter control, harmonics analysis using FFT.

TEXT BOOKS/ REFERENCES:

1. PICmicroTM Mid-Range MCU Family Reference Manual, 2017 Microchip Technology Inc., December 1997 /DS33023A.
2. Atmel-8271J-AVR- ATmega-Datasheet_11/2018.
3. PICmicroTM PIC16F87XA Data Sheet 28/40/44-Pin Enhanced Flash Microcontrollers, 2003 Microchip Technology Inc., DS39582B.
4. dsPIC30F Family Reference Manual, 2017 Microchip Technology Inc., DS70046E.
5. Richard C Dorf, "The Engineering Handbook," Second edition, CRC press, 2005.
6. Katsuhiko Ogata, "Discrete-time Control Systems," Pearson India, 2nd editon, 2015.

18PR624

RESTRUCTURED POWER SYSTEM OPTIMISATION

3-0-1-4

Review of power system operation in restructured scenario, marginal cost of generation, least-cost operation, and incremental cost of generation. Introduction to Power System Optimization: classical and evolutionary approaches of optimization, Formulation of optimal

power flow problem. Simulation: load flow and OPF studies using evolutionary approaches. Fundamentals of deregulation: Introduction to power systems restructuring, key issues in restructuring, restructuring models: Independent System Operators (ISOs). Electricity Markets: Competitive gencos and discos in markets, Supply and demand functions, Market equilibrium, types of electricity markets - inter-utility interchanges. Strategic bidding: Market power and its mitigation, Imperfect markets. Simulation: Electricity market clearing mechanism using OPF. Transmission Open Access: transmission costing, Concept of distribution factors in power transmission and its application to pricing, LMPs: Transmission capacity, ATC calculations, OASIS. Transmission Congestion Management and Transmission Rights. Simulation: Congestion management using evolutionary approaches. Ancillary Services: classifications and definitions, System Security in Deregulation. System Frequency Control: Primary Regulation and Automatic Generation Control, Frequency Control Practices, Reactive power ancillary services in electricity markets, Review of electric utility markets in India. Simulation: LFC studies.

TEXT BOOKS / REFERENCES:

1. D. P. Kothari, J. S. Dhillon, "Power System Optimization:", PHI Learning Pvt. Ltd., 2010.
2. Kankar Bhattacharya, Math H.J. Bollen and Jaap E. Daalder, "Operation of Restructured Power Systems", Springer. 2001.
3. M. Shahidehpour and M. Alomoush "Restructured Electrical Power Systems – Operation, Trading and Volatility", CRC Press. 2001.
4. M. Shahidehpour, H. Yamin and Zuyi Li, "Market Operations in Electric Power Systems: Forecasting, Scheduling, and Risk Management", Wiley-IEEE Press, 2002.
5. Loe Lie Lai "Power Systems Restructuring and Deregulation", John Wily, 2002.

18PR601 POWER ELECTRONICS FOR RENEWABLE ENERGY TECHNOLOGIES 2-0-2-4

Introduction to converters for renewable energy systems, DC-DC converters: Buck, boost, buck-boost, Ćuk converters: operation and waveforms in CCM and DCM. Forward, fly-back and push-pull converter circuits, half bridge, full bridge converters. Resonant DC-DC converters: operating principle, waveforms. Converter control: PWM, closed loop control, feed forward and current mode control. Driver circuits: unipolar, bipolar and isolated drives. Simulation of DC-DC converters with close loop control. Inverters: Overview, three phase converters, rectifier and inverter modes of operation for RL load. Inverter Control: PWM inverter modulation strategies, unipolar and bipolar switching scheme, sine wave PWM, space vector modulation, multi-level inverter - basic topology and waveform, improvement in harmonics. Converters in standalone power systems, Grid connected inverters. Simulation of inverter with different modulation strategies. Dynamic characteristics of power semiconductor switches: MOSFET, IGBT – switching trajectory and losses. Snubbers: turn-off and turn-on snubbers. Magnetic design: inductor and transformer design. Simulation: Snubber implementation in converter circuits. Laboratory Experiments in above modules

TEXT BOOKS/ REFERENCES:

1. Ned Mohan, Tore M. Undeland and William P. Robbins, “Power Electronics: Converters, Applications and Design”, Third Edition, John Wiley & Sons, 2007
2. L. Umanand, “Power Electronics: Essentials and Applications”, Wiley India, 2009.
3. Erickson, Maksimovic, and Dragan “Fundamentals of Power Electronics”, Kluwer academic publishers, 2001.

18PR626

SMART GRID

3-0-1-4

Smart Grids: Need and attributes, comparison with conventional power grid, Smart grid scenario in Indian power sector, smart grid architecture, Microgrid: Benefits, distributed generation, control, islanded and non-islanded operation, synchronous and asynchronous operation. Information and Communication technology : Smart sensors, Wired and wireless communication Technology, Network Structures(HAN, LAN, NAN, WAN), Phasor Measurement Units and applications, Geographical Information System, Data Analytics in the Smart Grid: Benefits, tools , Challenges , need of artificial intelligence and machine learning for Smart grid applications, Introduction to cloud computing, edge computing, security issues, Multi-agent technology in Smart grid, EMS/SCADA: RTU, IED, protocols and operations. Smart Meter Technology: Advanced meter Infrastructure, comparison of AMI and AMR. Demand Response Management: Energy efficiency, Energy Conservation, Demand response and HEMS. Power quality issues and need of power quality conditioner in off grid and grid connected renewable energy integrated systems. Storage Technology, Electric Vehicle Technology: EV, HEV, PHEV, smart parks. Operation & Control concepts in Smart grid: state estimation, load flow, optimal load flow, security constrained load flow, stability analysis, economic dispatch, self-healing, resilience and reliability. Case study and simulations: Substation automation, communication technology, electric vehicles, energy storage systems, demand response management, renewable energy and power quality.

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. JanakaEkanayake, N. Jenkins, K. Liyanage, J. Wu, Akihiko Yokoyama, “Smart Grid: Technology and Applications”, Wiley
4. Andres Carvello, John Cooper, “The Advanced Smart Grid”, ARTECH House, 2011.
5. White paper “Big Data Analytics, Machine Learning and Artificial Intelligence in the 7 Smart Grid: Introduction, Benefits, Challenges and Issues”, 2017.
6. Clark W. and Gellings, P.E., “The Smart Grid: Enabling Energy Efficiency and Demand Response”, The Fairmont Press, Taylor & Francis 2009.
7. Francis Vanek, Louis Albright and Largus Angenent, “Energy Systems Engineering Evaluation and Implementation”, McGraw Hill-2008.
8. Prabha Kundur, “Power System Stability and Control”, McGraw-Hill Education, 2011.
9. IEEE Power and Energy magazine.

18PR603

APPLICATION DEVELOPMENT LAB

0-0-3-2

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.

18RM600

RESEARCH METHODOLOGY

2-0-0-2

Unit I:

Meaning of Research, Types of Research, Research Process, Problem definition, Objectives of Research, Research Questions, Research design, Approaches to Research, Quantitative vs. Qualitative Approach, Understanding Theory, Building and Validating Theoretical Models, Exploratory vs. Confirmatory Research, Experimental vs Theoretical Research, Importance of reasoning in research.

Unit II:

Problem Formulation, Understanding Modeling & Simulation, Conducting Literature Review, Referencing, Information Sources, Information Retrieval, Role of libraries in Information Retrieval, Tools for identifying literatures, Indexing and abstracting services, Citation indexes

Unit III:

Experimental Research: Cause effect relationship, Development of Hypothesis, Measurement Systems Analysis, Error Propagation, Validity of experiments, Statistical Design of Experiments, Field Experiments, Data/Variable Types & Classification, Data collection, Numerical and Graphical Data Analysis: Sampling, Observation, Surveys, Inferential Statistics, and Interpretation of Results

Unit IV:

Preparation of Dissertation and Research Papers, Tables and illustrations, Guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript. References, Citation and listing system of documents

Unit V:

Intellectual property rights (IPR) - patents-copyrights-Trademarks-Industrial design geographical indication. Ethics of Research- Scientific Misconduct- Forms of Scientific Misconduct. Plagiarism, Unscientific practices in thesis work, Ethics in science

TEXT BOOKS/ REFERENCES:

1. Bordens, K. S. and Abbott, B. B., "Research Design and Methods – A Process Approach", 8th Edition, McGraw-Hill, 2011
2. C. R. Kothari, "Research Methodology – Methods and Techniques", 2nd Edition, New Age International Publishers
3. Davis, M., Davis K., and Dunagan M., "Scientific Papers and Presentations", 3rd Edition,

Elsevier Inc.

4. Michael P. Marder, "Research Methods for Science", Cambridge University Press, 2011
5. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008
6. Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age". Aspen Law & Business; 6 edition July 2012

18PR701

POWER PLANT INSTRUMENTATION

2-0-1-3

Introduction: Importance of Instrumentation and control in power generation, piping and instrumentation diagrams. Instrumentation and control in water circuit: boiler feed water circulation, measurements, controls, impurities in water and steam. Instrumentation and control in air-fuel circuit: measurements, controls, analytical measurements. Turbine monitoring and control: classification of turbines, instrumentation and 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. Basic principles of a nuclear plant. Nuclear power plant training simulator project. Design concepts of instrumentation and control of CWR, PWR and BWR reactors (different examples). Operator/Plant communication systems, main control systems, safety and safety related systems. Role of Instrumentation in hydroelectric power plant. Regulation and monitoring of voltage and frequency of output power. Pollution and effluent monitoring and control. Energy management. Electrical substation controls. Plant safety and redundancies of non conventional power plants. Diesel generator controls. Laboratory Practice: Simulation of intelligent control strategies in instrumentation, SCADA and so on.

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.
4. Singh S K, "Industrial Instrumentation and control" Tata- McGraw-Hill Publishing Company. 2009.
5. Nuclear power plant instrumentation and control, A guidebook, International atomic energy agency Vienna, 1984(online resource).
6. David Linsley, "Power plant control and instrumentation: The control of boilers and HRSG system", Institution of Electrical Engineers,. 2000.

18PR702

MATHEMATICAL MODELLING OF ENERGY SYSTEMS

2-0-1-3

Energy system modelling: background, motivations, modelling physical systems, time scales of power system dynamics, energy system architecture, energy system scripting, python language. Analysis of energy systems: power flow analysis, modelling and solution by Newton Raphson method, continuation power flow analysis, modelling and solution by homotopy methods, optimal power flow analysis, modelling and solution by gradient method. Modelling of Renewable Energy: operation of PV & Wind energy systems, frequency impact & voltage analysis, modelling of solid oxide fuel cell and battery energy storage. Modelling of HVDC transmission system and voltage source converter, modelling of STATCOM and

analysis. Dealing with uncertainty and probabilistic techniques: uncertainty power flow analysis and probabilistic optimal power flow analysis. Case studies of various analyses on standard IEEE test system.

TEXT BOOKS/ REFERENCES:

1. *Federico Milano, "Power System Modelling and Scripting", Springer Science & Business Media, 2010.*
2. *L.P. Singh, "Advanced Power System Analysis and Dynamics", New Age International, 2012.*
3. *Subhes C. Bhattacharyya, "Energy Economics: Concepts, Issues, Markets and Governance", Springer Science & Business Media, 2011.*
4. *Jizhong Zhu, "Optimization of Power System Operation", IEEE Press Series on Power Engineering, John Wiley & Sons, 2016.*
5. *S. S. Rao, "Engineering Optimisation: Theory and Practice", John Wiley and Sons, 2009.*

18PR703

ENERGY CONSERVATION AND MANAGEMENT

2-0-1-3

Energy Conservation and Management: general principles of energy management and energy management planning, conducting energy audit (pre-audit, audit and post-audit), energy audit instruments, energy audit report, monitoring, evaluating and following up energy saving measures/ projects, case study. Energy efficiency analysis, management of heating, Heat 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, Energy Efficiency in motors, pumps and fans, lighting, electrical load analysis, and peak demand control and Demand Response. 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: Time value of money - Present Worth and Future Worth Economic performance indices: Payback - Simple and Discounted, Net Present Value, Internal Rate of Return, Benefit to Cost Ratio, E/D ratio, Life cycle/levelized cost. Financial evaluation of energy projects, evaluation of proposals, profitability index, life cycle costing approach, investment decision and uncertainty. Energy conservation in vehicles, energy conservation in buildings, Power quality issues related to Energy Efficient Technologies, Energy Conservation Practice – Case Studies.

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).*
8. *Hamies, "Energy Auditing and Conservation; Methods, Measurements, Management and Case Study", Hemisphere Publishers, Washington, 1980.*
9. *C.W. Gellings and J.H. Chamberlin, "Demand-Side Management Planning", Fairmount Press, 1993.*
10. *Wayne C Turner, "Energy Management Handbook", The Fairmount Press, 2006.*
11. *Bureau of Energy Efficiency Study material for Energy Managers and Auditors Examination: Paper I to IV.*
12. *S. Pabla, "Electric Power Systems Planning", Mac Millan India Ltd., 1998.*

18PR704

ENERGY STORAGE TECHNOLOGY

2-0-1-3

Introduction to energy storage for power systems: Role of energy storage systems, applications. Overview of energy storage technologies: Thermal, Mechanical, Chemical, Electrochemical, Electrical. Efficiency of energy storage systems. Electrical energy storage: Batteries, Super capacitors, Superconducting Magnetic Energy Storage (SMES), charging methodologies, SoC, SoH estimation techniques. Hydrogen production and storage, fuel cells. Mobile storage system: electric vehicle, G2V, V2G. Hybrid Energy storage systems: configurations and applications. Storage for renewable energy systems: Solar energy, Wind energy, Pumped hydro energy, fuel cells. Energy storage in Microgrid and Smart grid. Energy Management with storage systems, Battery SCADA, Increase of energy conversion efficiencies by introducing energy storage. Laboratory experiments: Simulation of energy storage systems and its management, smart park, Electric Vehicle charging facility, HESS in microgrid and smart grid, microbial fuel cell, hydrogen fuel cell and so on.

TEXT BOOKS/ REFERENCES:

1. *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.*
2. *Francisco Díaz-González, Andreas Sumper, Oriol Gomis-Bellmunt," Energy Storage in Power Systems" Wiley Publication, ISBN: 978-1-118-97130-7, Mar 2016.*
3. *A. R. Pendse, "Energy Storage Science and Technology", SBS Publishers & Distributors Pvt. Ltd., New Delhi, (ISBN - 13:9789380090122), 2011.*
4. *Electric Power Research Institute (USA), "Electricity Energy Storage Technology Options: A White Paper Primer on Applications, Costs, and Benefits" (1020676), December 2010.*
5. *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.*

18PR705

ELECTRICAL DRIVES AND CONTROL

2-0-1-3

Fundamentals of electric drives, dynamics of electric drives, multi quadrant operation, closed loop control of drives. Review of DC and AC Motor Drives: 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

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. Computer aided designs. Simulations and case studies of classical controller design.

TEXT BOOKS/ REFERENCES:

1. *M. Gopal, "Modern Control System Theory", New Age International, 3rd edition, 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.*

18PR708 MACHINE LEARNING AND MULTIAGENT SYSTEM FOR POWER

ENGINEERING

2-0-1-3

Machine Learning: Linear Regression and Feature Selection, Analysis of variance for regression, Linear Classification, Support Vector Machines and Artificial Neural Networks, Bayesian Learning and Decision Trees, Evaluation Measures, Hypothesis Testing, Ensemble Methods, Clustering, Graphical Models, Learning Theory and Expectation Maximization, Introduction to Reinforcement Learning. Introduction to Multi Agent Systems: Intelligent Agents, design of intelligent agents, reasoning agents (eg. AgentO), agents as reactive systems (eg. subsumption architecture), hybrid agents (eg. PRS), layered agents (eg. InteRRaP) a contemporary (Java-based) framework for programming agents (eg JADE Java Agent Development Environment). Multi-Agent Systems: Classifying multi-agent interactions, cooperative versus non-competitive, zero-sum and other interactions, cooperation - the Prisoner's dilemma and Axelrod's experiments. Interactions between self-interested agents: auctions & voting systems: negotiation. Interactions between benevolent agents: cooperative distributed problem solving (CDPS), partial global planning; coherence and coordination; Interaction languages and protocols: speech acts, KQML/KIF, the FIPA framework. Case study, Coding and simulation works.

TEXT BOOKS/ REFERENCES:

1. *Christopher Bishop. "Pattern Recognition and Machine Learning", Second edition, Springer New York, 2016.*
2. *T. Hastie, R. Tibshirani, J. Friedman, "The Elements of Statistical Learning", Second edition. Springer series, 2013.*
3. *Michael Wooldridge, "An Introduction to MultiAgent Systems", Second Edition, Wiley, 2009.*
4. *Rafael H. Bordini, Jomi Fred Hubner and Michael Wooldridge, "Programming Multi-agent Systems in Agent Speak Using Jason". Wiley 2007.*

5. S. Russell and P. Norvig, "Artificial Intelligence – A Modern Approach", Prentice Hall, 2010.

18PR709 SMART ELECTRICAL NETWORKS AND INTELLIGENT

COMMUNICATION SYSTEMS

2-0-1-3

Data communication, Communication channels: Wireless and Wired communication. Layered architecture and protocols: ISO/OSI, TCP/IP models. Communication technologies: IEEE 802, Multi- protocol label switching, Power line communication. Protocols and standards for information exchange-Standards for smart metering, Modbus, DNP3 , IEC 61850, 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. Sensing measurement control and automation technologies. Communications infrastructure and protocols for smart metering: Home area network, Neighbourhood area network, Data concentrator, Meter data management system. Demand side integration- Services provided by DSI, Hardware support to DSI implementations, system support. Distribution automation equipment: Substation automation, IED, Remote terminal units. Distribution management systems, SCADA, Modelling and analysis tools. Application: System monitoring, operation and management, Interactions in autonomy-stability, Inference and predictions, hierarchical control, decentralized control, swarm robotics. Networked control systems- Time driven, Event driven feedback schemes.

TEXT BOOKS / REFERENCES:

1. J. Ekanayake, et al, "SMART GRID, Technology and Applications", Wiley, 2012.
2. Bernard Sklar., "Digital Communications", Second Edition, Pearson Education, 2001.
3. John G. Proakis., "Digital Communication", Fourth Edition, McGraw Hill Publication,2001.
4. Theodore S. Rappaport., "Wireless Communications", Second edition, Pearson Education, 2002.
5. Stephen G. Wilson., "Digital Modulation and Coding", First Indian Reprint Pearson Education,2003.
6. Clint Smith. P.E., and Daniel Collins, "3G Wireless Networks", Second Edition, Tata McGraw Hill, 2007.
7. Vijay. K. Garg, "Wireless Communication and Networking", Morgan Kaufmann Publishers, <http://books.elsevier.com/9780123735805;>,2007.
8. Kaveth Pahlavan. K. and Prashanth Krishnamurthy, "Principles of Wireless Networks", Prentice Hall of India, 2006.
9. Lubomir Bakule, "Decentralized control: An overview" Annual Reviews in Control, vol. 32, pp. 87-98, 2008.
10. Sokratis Kartakis , Anqi Fu, Manuel Mazo, Julie A. McCann, "Communication Schemes for Centralized and Decentralized Event-Triggered Control Systems" IEEE Transactions on Control Systems Technology, pp. 1-14, 2017.

18PR710 SOLAR ENERGY UTILISATION

2-0-1-3

Review of solar energy systems. Solar photovoltaic applications: types of systems, system design, balance of solar PV systems, Solar PV inverter & converter design, controllers, energy storage options for solar PV systems, battery & fuel cell, site selection for SPV

systems, design of off-grid, grid connected & hybrid PV systems, IEEE standards for grid integration, installation & maintenance of SPV plants, life cycle cost analysis, AI based solar energy forecasting. Solar Street lighting & water pumping applications: design considerations & system design. Solar energy collectors, concentrator and heliostat systems. Solar thermal system: space/ air heating & cooling, active & passive heating and cooling of buildings, solar dryers for process plants, solar pond, solar collector, solar thermal power plant and thermal storage: steady state and dynamic analysis, modelling of solar thermal systems and simulations in process design. Design of active systems by f-chart and utilisability methods. Thermoelectric-photovoltaic integrated modules for heating and electricity applications, solar hydrogen generation. Applications: Solar vehicle, Telecommunication, Naval and Space, ICT applications in solar energy sector. Simulation and case studies.

TEXT BOOKS/ REFERENCES:

1. Chetan Singh Solanki, “Solar Photovoltaics: Fundamentals, Technologies and Applications”, Second Edition, Prentice Hall of India, Third Edition, 2015.
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”, second edition, Taylor and Francis, Philadelphia, 2000.
4. Jeffrey R.S. Brownson “Solar Energy Conversion System” Academic press, Elsevier Inc. 2014.
5. Alireza Khaligh, Omer C. Onar “Energy Harvesting: Solar, Wind, and Ocean Energy Conversion Systems” Taylor and Francis CRC press, 2010.

18PR711

WIND ENERGY CONVERSION SYSTEMS

2-0-1-3

History of wind turbine development and trends. Review on wind resource assessment: wind regime modelling, measurement instruments, Weibull parameters, height dependency, wind resources worldwide and in India, wind energy forecast. Wind turbine: Review on basic aerodynamics, air foils, types and characteristics of wind turbine, turbine design, blade element theory, Betz limit, wake analysis, wind turbine 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. WTGS: 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, wind energy storage solutions. Control systems: requirements, components and strategies. Small wind turbines special considerations and designs, testing, noise issues, Off-shore turbines. Implementation: Site selection and turbine spacing, rotor selection, Annual Energy Output (AEO), optimal placement of wind turbine in a wind park, ICT based monitoring and control of wind farms. Financial considerations: installed costs, payback time, Levelized Energy Cost (LEC), simulation oriented case studies.

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. Earnest Joshua, "Wind Power Technology", Second edition, PHI Learning Pvt. Ltd., New Delhi, 2015.
4. Johnson G. L., "Wind Energy Systems", Prentice Hall, 1994 (published by the author online).
5. Spera D. A., "Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering", ASME Press, New York, 2009.
6. Voker Quashning, "Understanding Renewable Energy Systems", Earthscan, Second edition, 2016.
7. Tony Burton, David Sharpe, Nick Jenkins, Ervin Bossanyi, "Wind Energy Handbook" JOHN WILEY & SONS, LTD , Second Edition, 2011.
8. Freris. L. L., "Wind Energy Conversion Systems", Prentice Hall 1990.

18PR712

BIO-ENERGY CONVERSION

2-0-1-3

Bio-energy: Renewability and sustainability of biomass, origin of bio-mass (Photosynthetic process) sources, characteristics, Energy farming, biofuel production process, biomass conversion methods, pyrolysis, gasification, types of biomass gasification, biogas systems and classifications. 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, Microbial Fuel Cell, configurations, organic wastes to electricity, Waste to Energy (WTE) systems for Municipal Solid Wastes (MSW), vegetable, fish and meat processing residues for biodiesel production, bio-energy for stand- alone electrification, hybrid renewable energy systems. Simulation and case studies of above topics.

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.
4. G N Tiwari, M K Ghosal, "Fundamentals of Renewable Energy Sources", Narosa Publishing House, 2005.

18PR713 ADVANCED DIGITAL SIGNAL PROCESSORS AND APPLICATIONS

2-0-1-3

Pre-requisite: General background of microprocessors and microcontrollers. Overview on Digital signal controllers: C2000 modules, Piccolo based controllers, Delfino based controllers, dsPIC 30F series DSC, 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 dsPIC30F: 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. Introduction to Raspberry PI. Lab Practice: FIR/IIR Filters, FFT, PID control loops and communication systems using dsPIC30F2010.

Installing Linux OS, Installing and using OpenCV image processing library and basic python using Raspberry PI.

TEXT BOOKS/ REFERENCES:

1. *dsPIC30F Family Reference manual, Microchip 2008.*
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. *Byron Francis, "Raspberry PI 3: The Complete Beginner's Guide," Create Space Independent Publishing Platform, 2016.*

18PR714

ELECTRIC VEHICLE TECHNOLOGY

2-0-1-3

Review of Conventional Vehicle: Introduction to Hybrid Electric Vehicles: Types of EVs, Hybrid Electric Drive-train, Tractive effort in normal driving, Energy consumption Concept of Hybrid Electric Drive Trains, Architecture of Hybrid Electric Drive Trains, Series Hybrid Electric Drive Trains, Parallel hybrid electric drive trains, Electric Propulsion unit, Configuration and control of DC Motor drives, Induction Motor drives, Permanent Magnet Motor drives, switched reluctance motor, Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles:- Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Hybridization of different energy storage devices. Sizing the drive system, Design of Hybrid Electric Vehicle and Plug-in Electric Vehicle, Energy Management Strategies, Automotive networking and communication, EV and EV charging standards, V2G, G2V, V2B, V2H. Business: E-mobility business, electrification challenges, Business- E-mobility business, electrification challenges, Connected Mobility and Autonomous Mobility- case study E-mobility Indian Roadmap Perspective. Policy: EVs in infrastructure system, integration of EVs in smart grid, social dimensions of EVs. Simulations and case studies in above mentioned areas.

TEXT BOOKS/ REFERENCES:

1. *Emadi, A. (Ed.), Miller, J., Ehsani, M., "Vehicular Electric Power Systems" Boca Raton, CRC Press, 2003.*
2. *Husain, I. "Electric and Hybrid Vehicles" Boca Raton, CRC Press, 2010.*
3. *Larminie, James, and John Lowry, "Electric Vehicle Technology Explained" John Wiley and Sons, 2012.*
4. *Tariq Muneer and Irene Illescas García, "The automobile, In Electric Vehicles: Prospects and Challenges", Elsevier, 2017.*
5. *Sheldon S. Williamson, "Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles", Springer, 2013.*

18PR715

CYBER PHYSICAL SYSTEMS

2-0-1-3

Cyber-Physical Systems (CPS) in the real world, Basic principles of design and validation of CPS, CPS HW platforms: Processors, Sensors, Actuators, CPS Network, CPS SW stack RTOS, Scheduling Real Time control tasks. Principles of Automated Control Design:

Dynamical Systems and Stability, Controller Design Techniques. Stability Analysis: CLFs, MLFs, stability under slow switching, Performance under Packet drop and Noise. CPS : From features to software components, Mapping software components to ECUs, CPS Performance Analysis : effect of scheduling, bus latency, sense and actuation faults on control performance, network congestion, Formal Methods for Safety Assurance of Cyber-Physical Systems: Advanced Automata based modelling and analysis: Basic introduction and examples ,Timed and Hybrid Automata, Definition of trajectories, zenoness, Formal Analysis: Flow pipe construction, reachability analysis, Analysis of CPS Software, Weakest Pre-conditions, Bounded Model checking, Hybrid Automata Modelling : Flowpipe construction using Flowstar, SpaceX and Phaver tools, CPS SW Verification: Frama-C, CBMC, Secure Deployment of CPS : Attack models, Secure Task mapping and Partitioning, State estimation for attack detection, Automotive Case study : Vehicle ABS hacking, Power Distribution Case study : Attacks on Smart grid.

TEXT BOOKS/ REFERENCES:

1. E. A. Lee and S. A. Seshia, *“Introduction to Embedded Systems: A Cyber-Physical Systems Approach”*, 2011.
2. R. Alur, *“Principles of Cyber-Physical Systems,”* MIT Press, 2015.
3. T. D. Lewis *“Network Science: Theory and Applications”*, Wiley, 2009.
4. P. Tabuada, *“Verification and control of hybrid systems: a symbolic approach”*, Springer-Verlag 2009.
5. C. Cassandras, S. Lafortune, *“Introduction to Discrete Event Systems”*, Springer 2007.
6. Constance Heitmeyer and Dino Mandrioli, *“Formal methods for real-time computing”*, Wiley publisher, 1996.

18PR716

ICT ENABLED POWER SYSTEM PROTECTION

2-0-1-3

IEEE Protection Standards & Guides, Protection Characteristics: Reliability, Security, Speed, Selectivity, And Economics, Review of protection schemes: Over-current protection Differential Protection, Distance protection, quadrilateral relay, elliptical relay. Numerical relay: principles, Data Acquisition Systems, RTU, IED, Synchrophasor based Wide Area Monitoring Systems (WAMS): PMU, Data Sampling and signal conditioning, Use of FFT, DFT, Wavelet for protection algorithms. Fault location and identification. Information and Communication Technology application to protective systems: ICT functions, ICT control of network for protection coordination, Common Format for Transient Data Exchange (COMTRADE). Protection in Distributed Generators (DGs), micro grids and smart grids. Power system protection testing: automatic testing, test methods, maintenance and field testing of relays, Case study and simulations: ICT based fault detection identification and classification, Adaptive protection coordination. Laboratories: Testing of numerical over current relays, under/over frequency relays & differential relays.

TEXT BOOKS/ REFERENCES:

1. T.S.M. Rao *“Digital/Numerical Relays”* Tata McGraw-Hill Education, 01-Jul-2005.
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. Y.G. Paithankar and S.R Bhide, *“Fundamentals of Power System Protection”*, Prentice-Hall of India, 2003.
5. *IEEE standards, Transaction papers on power system protection.*

