M.TECH. – POWER AND ENERGY (SMARTGRIDS AND ELECTRIC VEHICLES)

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

The restructuring and deregulation of electric utilities together with recent progress in Smart grid andRenewable Energy Technologies introduce unprecedented challenges and wide scope forpower and energy systems research and open up new opportunities to young PowerEngineers. The advancement in Power & Energy with the vision of redefining theConventional Power System as an Intelligent Power Grid with a blend of the latesttechnologies like Smart Sensing, Cyber Physical System and ICT coupled with RenewableEnergy Sources, Electric Vehicle, and Energy Storage etc. will be the key factors to asustainable world for future generations.

M. Tech. program in Power and Energy is intended to explore the above mentionedchallenges and also to initiate intense research activities. The structure of lab oriented courseswill enable the students to have an insight into the real time scenarios and can build athorough understanding of the systems as a whole. The Power and Energy courses emphasison various streams like Smartgrids, Electric Vehicles, Power System, Sustainable and Renewable Energy,Computational and Communication Technology Applications, Power Electronics andControl, and Embedded Systems. This programs aims to make studentsemployable in various sectors of Power & Energy, Communication, Smartgrid, ElectricTransport, Petroleum Industry, Energy Management and Conservations etc. and to impartinterest in carrying out high end research activities in these areas.

CURRICULUM

FIRST SEMESTER

Course Code	Type	Course	L-T-P	Credit
19MA604	FC	Software Based Numerical Computation Methods	2-0-2	3
19PR611	SC	Power System Planning, Operation and Control	3-0-2	4
19PR612	SC	Sustainable and Renewable Energy Technology	2-0-2	3
19PR601	FC	Power Electronic Converters for Smartgrids and Electric Vehicles	2-0-2	3
19PR613	SC	Smartgrid	3-0-0	3
19PR614	SC	Electric Vehicle Technology	2-0-2	3
19PR602	FC	Digital Signal Controllers	3-0-2	4
19HU601	HU	Amrita Values Program*		P/F
19HU602	HU	Career Competency I*		P/F
		Credits		**23**

***** Non-credit course

SECOND SEMESTER

Course Code	Type	Course	L-T-P	Credit
19PR615	SC	Restructured Power System Optimisation	2-0-2	3
19PR603	FC	Power Quality and FACTS	2-0-2	3
19PR616	SC	Intelligence& Communication in Smartgrid	2-0-2	3
19PR617	SC	Vehicular Networks and communications	2-0-2	3
	E	Elective 1	3-0-0	3
	E	Elective 2	3-0-0	3
19PR618	SC	Application Development lab	1-0-2	2
19HU603	HU	Career Competency II	0-0-2	1
19RM600	SC	Research Methodology	2-0-0	2
		Credits		**23**

THIRD SEMESTER

Course code	Type	Course	Credit
19PR798	P	Dissertation	10

FOURTH SEMESTER

Course code	Type	Course	Credit
19PR799	P	Dissertation	10
		Credits	10

Total Credits: 66

LIST OF COURSES

Foundation Core (FC)

Course Code	Course	L – T – P	Credits
19PR601	Power Electronic Converters for Smartgrids and Electric Vehicles	2-0-2	3
19PR602	Digital Signal Controllers	3-0-2	4
19PR603	Power Quality and FACTS	2-0-2	3
19MA604	Software Based Numerical Computation Methods	2-0-2	3

Subject Core (SC)

Course Code	Course	L – T – P	Credits
19PR611	Power System Planning, Operation and Control	3-0-2	4
19PR612	Sustainable and Renewable Energy Technology	2-0-2	3
19PR613	Smartgrid	3-0-0	3
19PR614	Electric Vehicle Technology	2-0-2	3
19PR615	Restructured Power System Optimisation	2-0-2	3
19PR616	Intelligence & Communication in Smartgrid	2-0-2	3
19PR617	Vehicular Networks and communications	2-0-2	3
19PR618	Application Development lab	1-0-2	2
19RM600	Research Methodology	2-0-0	2

ELECTIVES -I

(Subjects include areas from Power System, Sustainable and Renewable Energy, Computational and Communication Technology, Power Electronics ,Control and Smartgrid**)**

Course Code	Course	L – T – P	Credits
19PR701	Energy Storage Technology	3-0-0	3
19PR702	ICT enabled Power System Protection	3-0-0	3
19PR703	Advanced Digital Signal Controllers and Applications	3-0-0	3
19PR704	Machine learning and Multi Agent Systems for Power Engineering	3-0-0	3
19PR705	Mathematical Modelling of Energy Systems	3-0-0	3
19PR706	Cyber Physical Systems	3-0-0	3
19PR707	Energy Conservation and Management	3-0-0	3
19PR708	Solar Energy Utilisation	3-0-0	3
19PR709	Wind Energy Conversion Systems	3-0-0	3
19PR710	Power Plant Instrumentation	3-0-0	3
19PR711	Computational Intelligence for Power Applications	3-0-0	3
19PR712	Bio- Energy Conversion	3-0-0	3

ELECTIVES -II

(Subjects include areas from Automotive applications and Electric Vehicles)

Course Code	Course	L – T – P	Credits
19PR721	Advanced Power Electronics for Automotive Applications	3-0-0	3
19PR722	System Engineering and Integration	3-0-0	3
19PR723	Electric Drives And Control	3-0-0	3
19PR724	Control System Design	3-0-0	3
19PR725	E-mobility Business and policies	3-0-0	3
19PR726	Automotive Electronics	3-0-0	3
19PR727	Automotive Control System	3-0-0	3
19PR728	Vehicle Dynamics and Control	3-0-0	3

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

Project Work

Course Code	Course	L – T – P	Credits
19PR798	Dissertation I		10
19PR799	Dissertation II		10

19PR601 POWER ELECTRONICS CONVERTERS FOR SMARTGRIDS AND ELECTRIC VEHICLES 2-0-2-3

Introduction to converters for DGs in Smart Grid, DC-DC converters: Buck, boost,buck-boost,. Forward, fly-backand push-pull converter circuits, half bridge, full bridge converters. Resonant DC-DC converters: operating principle, waveforms.cascaded DC-DC and DC-AC converters (DC-link) and cascaded DC-AC and AC-AC converters (high-frequency link), Z-source converter,bi directional DC-DC converter, 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. Converters for Electric Vehicle charging terminals: AC/DC bi-directional converter,DC/DC bi-directional converter, 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.Snubbers: turnoff and turn-on snubbers. Magnetic design: inductor and transformer design. Simulation of power electronic converters in Smartgrids and Electric Vehicles.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.*
4. *B K Bose, "Modern Power Electronics and AC Drives"Pearson publications,1st edition*
5. *R. Erickson, D. Maksimovic, Fundamentals of Power Electronics, Springer 2001*
6. *Ehab H E Bayoumi,"Power electronics in smart grid distribution power systems: A review"-International Journal of Industrial Electronics*
7. *G.Benysek, M.P. Kazmierkowski, J.Popczyk, And R. Strzelecki "Power electronic systems as a crucial part of Smart Grid infrastructure – a survey" Bulletin Of The Polish Academy Of Sciences,Technical Sciences, Vol. 59, No. 4, 2011*
8. *Selected transactions on Electric vehicles and Smartgrids*

19PR602 DIGITAL SIGNAL CONTROLLERS 3-0-2-4

Digital Signal controllers: 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.Simulation/hardware experiments with latest digital signal controllers. Lab Practice: Interfacing power electronic switches, voltage and current measurement techniques, digital ammeter and voltmeter, PWM generation for Servo Motor control, harmonics analysis in DSC using FFT.

TEXTBOOKS/ REFERENCES:

1. *dsPIC30F Family Reference Manual, 2017 Microchip Technology Inc., DS70046E.*
2. *dsPIC30F Programmer's Reference manual, Microchip, 2008.*
3. *PICmicro™ Mid-Range MCU Family Reference Manual, 2017 Microchip Technology Inc., December 1997 /DS33023A. Atmel-8271J-AVR- ATmega-Datasheet_11/2018.*
4. *PICmicro™PIC16F87XA Data Sheet 28/40/44-Pin Enhanced Flash*
5. *. Microcontrollers, 2003 Microchip Technology Inc., DS39582B.*
6. *Richard C Dorf, "The Engineering Handbook," Second edition, CRC press, 2005.*

19PR603 POWER QUALITY AND FACTS 2-0-2-3

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

19MA604 SOFTWARE BASED NUMERICAL COMPUTATION METHODS

2-0-2-3

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-Jordon method and iterative methods, inverse of a matrix by Gauss Jordon 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 powerflow, 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", Addition 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.*

19PR611 POWER SYSTEM PLANNING, OPERATION AND CONTROL

3-0-2-4

Introduction to planning operation and control. Objectives of planning: Long and short term planning, load forecasting, advanced methodologies. Economic operation: Review of thermalunits, 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 YasunoriMitani, "Power System Monitoring and Control", Wiley-IEEE Press, 2014.*
6. *PrabhaKundur, "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.*

19PR612 SUSTAINABLE AND RENEWABLE ENERGY TECHNOLOGY

2-0-2-3

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 (UNFCC) 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 Johanssson 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 Bhdra S N, " Wind Electrical Systems", Oxford University Press, New Delhi, 1998.*
7. *Tony Burton, David Sharpe, Nick Jemkins and Ervin Bossanyi., "Wind Energy HandBook", John Wiley & Sons, 2004.*
8. *Chetan S. Solanki, "Solar Photovoltaics: Fundamentals, Technologies and Applications", Second Edition, PHI Publications, 2011*

19PR613 SMART GRID 3-0-0-3

Smart Grids: Smart grid landscape and its characteristics; smart grid architecture; Smart grid scenario in Indian power sector; Smart grid technologies: Information and Communication Technology: Smart sensors, Wired and wireless communication Technology, Network Structures (HAN, LAN, NAN, WAN); Smart sensors, Smart Metering and advanced metering infrastructure (AMI) ; Monitoring smart grid: Intelligent Electronic Devices (IED), wide-area monitoring system (WAMS), SCADA, Phasor Measurement Units s, Geographical Information System; Penetration of Clean Energy Technologies; Storage Technology, Geomagnetic Storms as Generators, Near space power generation, Electric Vehicle Technology ; Power electronics and power quality in Smart grid; Block chain Technology in Smart grid; Multi-agent technology in Smart grid; Superconducting Technologies- Superconducting power cables, Wireless Power Transmission technology; Smart grid operation & control, self-healing, Resilience, E-Commerce of Electricity, Case study on substation automation; Micro grid: Integration of distributed energy sources, operation, control and protection of Micro grid, Overview of generation, transmission and distribution automation. IoT in Smart Grid: IoT Architecture and its application; Introduction to cloud computing and edge computing application in smart grid, Standards for Information Exchange - Data Security methods; Embedded web servers, Energy Data Analytics in the Smart Grid-Sources , Characteristics, Need, Tools, and Challenges; Artificial Intelligence, Machine Learning and M2M applications in Smart grid applications.
Case study/Simulation/Hardware experiments.

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,2004.*
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 Smart Grid: Introduction, Benefits, Challenges and Issues", 2017.*
6. *IEEE Power and Energy magazine,2002.*

19PR614 ELECTRIC VEHICLE TECHNOLOGY 2-0-2-3

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 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.
Case study/Simulation/Hardware experiments

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 IllescasGarcía, "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*

19PR615 RESTRUCTURED POWER SYSTEM OPTIMISATION 2-0-2-3

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:*
5. *Forecasting, Scheduling, and Risk Management", Wiley-IEEE Press, 2002.*
6. *Loe Lie Lai "Power Systems Restructuring and Deregulation", John Wily, 2002.*

19PR616 INTELLIGENCE & COMMUNICATION IN SMARTGRID2-0-2-3

Need of intelligence and communication in Smart Grid, Case Study on Postmortem Analysis of Blackouts Drivers Toward the Smart Grid; NETWORK layered ARCHITECTURE, Protocols and standards for information exchange- Advanced Metering Infrastructure Protocols aiding AMI IEEE 802.15.4, 6LoWPAN, ROLL, and RPL, IEEE 802.11 255, 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. Techniques for sensing: Phasor measurement units, Compressive sensing, Decentralized and cooperative sensing; Techniques for sensor communications: Machine-to-machine communications, Cooperative communications, Cognitive radio (CR); Medium access control, routing, and transport protocols for sensor data communications; Networked control systems- Time driven, Event driven feedback schemes. Substation Automation Architecture; Data Analytics: Big Data Collection, sampling and preprocessing; Smart Grid Data Analytics : Event Analytics, State Analytics, Customer Analytics, data analytics platform and Operational Analytics ; Big Data Architecture and Platforms ; Application of Big Data in Smart Grids - Intelligent Sensing : missing sensor restoration (MSR) , Monitoring and Identification : PMU for system Identification and state estimation, Power System Operation Support : Forecasting - time series analysis, regression analysis and other statistical methods; ANN short-term load forecaster, Physics-based numerical weather prediction (NWP) , Scheduling : deterministic optimization methods , Security

Assessment: Online dynamic security assessment (DSA) , Power System Control: Wide-Area Damping Control Local damping controllers, Wide-Area Power Flow Control; Power System Protection: Intelligent/Adaptive Relays, Current Limiters , Intelligent Auto-Reclosers, Intelligent Fault Locating, Distribution optimization ; Nanoscale Communication Networks.
Case study/Simulation/Hardware experiments

TEXT BOOK/REFERENCES:

1. *Stephen F. Bush, "Smart Grid: Communication-Enabled Intelligence for the Electric Power Grid" ISBN: 978-1-119-97580-9 March 2014 Wiley-IEEE Press*
2. *Fadlullah, Zubair& Fouda, Mostafa& Kato, Nei& Takeuchi, Akira & Iwasaki, Noboru & Nozaki, Yousuke,2011.*
3. *Toward Intelligent Machine-to-Machine Communications in Smart Grid. Communications Magazine, IEEE. 49. 60 - 65. 10.1109/MCOM.2011.5741147,2011.*
4. *Kaveth Pahlavan. K. and Prashanth Krishnamurthy, "Principles of Wireless Networks", Prentice Hall of India, 2006.*
5. *Bart Baesens"Analytics in a Big data world" Wiley Publications,2004*

19PR617 VEHICULAR NETWORKS AND COMMUNICATIONS 2-0-2-3

Vehicular Networks: Cross-System Functions, Requirements For Bus Systems, Classification of Bus Systems, Application In The Vehicle, Coupling of Networks, Examples of Networked Vehicles; Bus Systems: CAN Bus , CAN-FD, LIN Bus, MOST Bus Bluetooth, Flex Ray, Diagnostic Interfaces: Implementation of Body Electronics Functionalities Using Controllers.

Vehicular Communications: Intelligent Transportation Systems: IEEE 802.11p-ITS-IVC: Inter-Vehicle Communications- Mobile Wireless Communications And Networks- Architecture Layers-Communication Regime.V2V, V2I-VANET-WAVE;DSRC. Information In The Vehicle Network- Routing-Physical Layer Technologies-Medium Access For Vehicular Communications- Security-Applications And Case Studies.

Lab Experiments Based On Various Vehicular Communication/Network Protocols/Standards

TEXT BOOKS/REFERENCES:

1. *Dominique Paret, "Multiplexed Networks for Embedded Systems: CAN, LIN, FlexRay, Safe-by-Wire", Wiley,2007.*
2. *Dominique Paret, "FlexRay and its Applications: Real Time Multiplexed Networks", Second Edition, Wiley,2012.*
3. *Popescu-Zeletin R, Radusch I and Rigani M.A, "Vehicular-2-X Communication", Springer,2010.*
4. *Xiang W, "Wireless Access in Vehicular Environments Technology", Springer, 2015.*
5. *Laun T.H, Shen X.(Sherman) and Bai F, "Enabling Content Distribution in Vehicular AdHoc Networks", Springer, 2014.*

19PR618APPLICATION DEVELOPMENT LAB 1-0-2-2

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 andkits (Microcontrollers, FPGA kits etc) to prepare students for project phase

19RM600 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 LiteratureReview, Referencing, Information Sources, Information Retrieval, Role of libraries inInformation 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 ofExperiments, Field Experiments, Data/Variable Types & Classification, Data collection,Numerical and Graphical Data Analysis: Sampling, Observation, Surveys, InferentialStatistics, and Interpretation of Results

Unit IV:

Preparation of Dissertation and Research Papers, Tables and illustrations, Guidelines forwriting 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 designgeographical indication. Ethics of Research- Scientific Misconduct- Forms of ScientificMisconduct. 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*

19PR701 ENERGY STORAGE TECHNOLOGY 3-0-0-3

Introduction to energy storage for power systems**:** Need and role of energy storage systems in power system, General considerations, Energy and power balance in a storage unit, Mathematical model of storage, Econometric model of storage.

Overview on Energy storage technologies: Potential energy (Pumped hydro, Compressed Air,) - Kinetic energy (Mechanical- Flywheel) - Thermal energy without phase change passive (adobe) and active (water) - Thermal energy with phase change (ice, molten salts, steam) - Chemical energy (hydrogen, methane,) - Electrochemical energy (Batteries, Fuel cells) - Electrostatic

energy (Super Capacitors), Electromagnetic energy (Super conducting Magnetic Energy Storage) - Different Types of Energy Storage Systems comparative analysis, Comparison of environmental impacts for different technologies.
Energy storage Applications**:**Renewable energy generation- Solar energy, Wind Energy, pumped hydro energy, fuel cells, battery Storage- types, charging methodologies, SoC, SoH estimation techniques, Hydrogen production methods and storage.
Smart Grid, Smart Microgrid, Smart House,
Mobile storage system:Electric vehicles -G2V, V2G, Management and control hierarchy of storage systems - Aggregating EES systems and distributed generation (Virtual Power Plant Energy Management with storage systems, Battery SCADA, Hybrid Energy storage systems: configurations and applications
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. *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*

19PR702ICT ENABLED POWER SYSTEM PROTECTION3-0-0-3

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. Numericalrelay: principles, Data Acquisition Systems, RTU, IED, Synchrophasor based Wide AreaMonitoring Systems (WAMS): PMU, Data Sampling and signal conditioning, Use of FFT,DFT, Wavelet for protection algorithms. Fault location and identification. Information andCommunication Technology application to protective systems: ICT functions, ICT control ofnetwork 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 andclassification, Adaptive protection coordination. Laboratories: Testing of numerical overcurrent 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.*

19PR703 ADVANCED DIGITAL SIGNAL CONTROLLERS AND APPLICATIONS 3-0-0-3

Pre-requisite: General background of microprocessors and microcontrollers.

Overview of Digital signal controllers: C2000 modules, Piccolo based controllers,Delfino based controllers, MAC units, hardware divide support, floating point signal processing support. dsPIC30F series DSC- 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. Lab Practice: FIR/IIR Filters, FFT, PID control loops and communication systems using dsPIC30F2010.

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 PI3: The Complete Beginner's Guide,"Create Space Independent Publishing Platform, 2016*

19PR704 MACHINE LEARNING AND MULTIAGENT SYSTEMS FOR POWER ENGINEERING 3-0-0-3

Machine Learning: Linear Regression and Feature Selection, Analysis of variance forregression, 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: IntelligentAgents, design of intelligent agents, reasoning agents (eg. AgentO), agents as reactivesystems (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-agentinteractions, cooperative versus non-competitive, zero-sum and other interactions,cooperation - the Prisoner's dilemma and Axelrod's experiments. Interactions between self-interestedagents: auctions & voting systems: negotiation. Interactions between benevolentagents: cooperative distributed problem solving (CDPS), partial global planning; coherenceand coordination; Interaction languages and protocols: speech acts, KQML/KIF, the FIPAframework. 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.*
4. *Michael Wooldridge, "An Introduction to MultiAgent Systems", Second Edition, Wiley,2009.*
5. *Rafael H. Bordini, Jomi Fred Hubner and Michael Wooldridge, "Programming MultiagentSystems in Agent Speak Using Jason". Wiley 2007*

19PR705MATHEMATICAL MODELLING OF ENERGY SYSTEMS 3-0-0-3

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 byNewton Raphson method, continuation power flow analysis, modelling and solution byhomotopy 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. Modellingof HVDC transmission system and voltage source converter, modelling of STATCOM andanalysis. Dealing with uncertainty and probabilistic techniques: uncertainty power flowanalysis and probabilistic optimal power flow analysis. Case studies of various analyses onstandard 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*

19PR706CYBER PHYSICAL SYSTEMS 3-0-0-3

Cyber-Physical Systems (CPS) in the real world, Basic principles of design and validationof

CPS, CPS HW platforms: Processors, Sensors, Actuators, CPS Network, CPS SW stackRTOS, 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 : Fromfeatures to software components, Mapping software components to ECUs, CPS PerformanceAnalysis : effect of scheduling, bus latency, sense and actuation faults on ontrolperformance, network congestion, Formal Methods for Safety Assurance of Cyber-PhysicalSystems: Advanced Automata based modelling and analysis: Basic introduction andexamples ,Timed and Hybrid Automata, Definition of trajectories, zenoness, FormalAnalysis: Flow pipe construction, reachability analysis, Analysis of CPS Software, WeakestPre-conditions, Bounded Model checking, Hybrid Automata Modelling : Flowpipeconstruction 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, PowerDistribution 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*

19PR707 ENERGY CONSERVATION AND MANAGEMENT 3-0-0-3

Energy Conservation and Management: general principles of energy management and energymanagement planning, conducting energy audit (pre-audit, audit and post-audit), energy auditinstruments, energy audit report, monitoring, evaluating and following up energy saving measures/ projects, case study. Energy efficiency analysis, management of heating, HeatVentilating and Air-Conditioning (HVAC), management of process energy, Energy efficiency of turbines, compressors and pumps, specific energy consumption, parametersaffecting specific energy consumption, flexi targeting technique. Cogeneration: types andschemes, case study. Management of electrical load and lighting: Management opportunitieswith electric drives, Energy Efficiency in motors, pumps and fans, lighting, electrical loadanalysis, and peak demand control and Demand Response. Economics of power factorimprovement: reactive power management, capacitor sizing, location, placement,maintenance, case study. Computer -aided energy management, energy efficiency policyinitiatives. Energy Economics: Time value of money - Present Worth and Future WorthEconomic performance indices: Payback - Simple and Discounted, Net Present Value,Internal Rate of Return, Benefit to Cost Ratio, E/D ratio, Life cycle/levelized cost. Financialevaluation of energy projects, evaluation of proposals, profitability index, life cycle costingapproach, investment decision and uncertainty. Energy conservation in vehicles, energyconservation 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, 2*

19PR708SOLAR ENERGY UTILISATION 3-0-0-3

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 SPVsystems, design of off-grid, grid connected & hybrid PV systems, IEEE standards for gridintegration, installation & maintenance of SPV plants, life cycle cost analysis, AI based solarenergy forecasting. Solar Street lighting & water pumping applications: design considerations& system design. Solar energy collectors, concentrator and heliostat systems. Solar thermalsystem: space/ air heating & cooling, active & passive heating and cooling of buildings, solardryers for process plants, solar pond, solar collector, solar thermal power plant and thermalstorage: steady state and dynamic analysis, modelling of solar thermal systems andsimulations in process design. Design of active systems by f-chart and utilisabilitymethods.Thermoelectric-photovoltaic integrated modules for heating and electricity applications, solarhydrogen generation. Applications: Solar vehicle, Telecommunication, Naval and Space, ICTapplications 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. *AlirezaKhaligh, Omer C. Onar "Energy Harvesting: Solar, Wind, and Ocean Energy Conversion Systems" Taylor and Francis CRC press, 2010*

19PR709WIND ENERGY CONVERSION SYSTEMS 3-0-0-3

History of wind turbine development and trends. Review on wind resource assessment: windregime modelling, measurement instruments, Weibull parameters, height dependency, windresources worldwide and in India, wind energy forecast. Wind turbine: Review on basicaerodynamics, air foils, types and characteristics of wind turbine, turbine design, bladeelement theory, Betz limit, wake analysis, wind turbine rotor design considerations, numberof blades, blade profile, 2/3 blades and teetering, coning, power regulation, wind turbineloads, aerodynamic loads in steady operation, wind turbulence, and tower shadow, windturbine components, braking, yaw system, tower, others. WTGS: Fixed speed and

variablespeed systems. Electrical machines for wind energy systems, synchronous and asynchronousgenerators 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 anddesigns, testing, noise issues, Off-shore turbines. Implementation: Site selection and turbinespacing, 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. *VokerQuashning, "Understanding Renewable Energy Systems", Earthscan, Second edition, 2016.*
7. *Tony Burton, David Sharpe, Nick Jenkins, Ervin Bossanyi, "Wind Energy Handbook" johnwiley& sons, ltd , Second Edition,2011*

19PR710POWER PLANT INSTRUMENTATION 3-0-0-3

Introduction: Importance of Instrumentation and control in power generation, piping andinstrumentation diagrams. Instrumentation and control in water circuit: boiler feed watercirculation, measurements, controls, impurities in water and steam. Instrumentation andcontrol in air-fuel circuit: measurements, controls, analytical measurements. Turbinemonitoring and control: classification of turbines, instrumentation and control points of view,principal parts of turbines, turbine steam inlet system, turbine measurements, turbine controlsystem, lubrication for turbo-alternator, turbo alternator cooling system. Basic principles of anuclear plant. Nuclear power plant training simulator project. Design concepts ofinstrumentation and control of CWR, PWR and BWR reactors (differentexamples).Operator/Plant communication systems, main control systems, safety and safetyrelated systems. Role of Instrumentation in hydroelectric power plant. Regulation andmonitoring of voltage and frequency of output power. Pollution and effluent monitoring andcontrol. Energy management. Electrical substation controls. Plant safety and redundancies ofnon-conventional power plants. Diesel generator controls. Laboratory Practice: Simulation ofintelligent 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.*

19PR711 COMPUTATIONAL INTELLIGENCE FOR POWER APPLICATIONS 3-0-0-3

Introduction to Computational Intelligence, Intelligence machines, Computationalintelligence paradigms, Rule-Based Expert Systems and Fuzzy Expert Systems, Rule-basedexpert systems, Uncertainty management, Fuzzy sets and operations of fuzzy sets, Fuzzyrules and fuzzy inference, Fuzzy expert systems, Case study: fuzzy logic controller forwashing 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, simplerecurrent neural networks, time-delay neural networks, supervised learning algorithms,Un-supervised learning neural networks: self-organizing feature maps, Radial basis functionnetworks,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-fuzzysystems, 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. *LaureneFausett, "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*

19PR712 BIO-ENERGY CONVERSION 3-0-0-3

Bio-energy: Renewability and sustainability of biomass, origin of bio-mass (Photosyntheticprocess) sources, characteristics, Energy farming, biofuel production process,

biomassconversion methods, pyrolysis, gasification, types of biomass gasification, biogas systemsand classifications. Anaerobic digestion of wastes, high performance bio-gas systems,cleaning of bio-gas, use of bio- mass for electricity production, bio-gas compression andstorage. Micro algae for oil production, Straight Vegetable Oil (SVO) in engines, MicrobialFuel Cell, configurations, organic wastes to electricity, Waste to Energy (WTE) systems forMunicipal Solid Wastes (MSW), vegetable, fish and meat processing residues for biodieselproduction, bio-energy for stand- alone electrification, hybrid renewable energy systems.Simulation and case studies of above topics

TEXT BOOKS/ REFERENCES:

1.*PrabirBasu, "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.

19PR721 ADVANCED POWER ELECTRONICS FOR AUTOMOTIVE

APPLICATIONS 3-0-0-3

Evolution of the Distribution Electrical Systems: Electrical and Electronics Systems In The Vehicle, Conventional System of Electrical Distribution In Automobile, Peaking Power Sources And Energy Storage: Fuel Cells, Batteries, Super Capacitors, Flywheel And Hybridization of Energy Storage. Role of Power Electronics In Vehicles, Characteristics of Power Semiconductor Switches- Power Diodes, Power Transistors And Thyristors, Selection of Devices.

Power Electronics Converters: Review of AC-DC Converters, DC-DC Converters, AC-AC Converters, DC-AC Converters Electric Propulsion Systems: DC Motor Drive: Basic Characteristics, Combined Armature Voltage Ad Field Control, Operating Modes, Chopper

Drives, Regenerative Braking, Effects Of Changes In Supply Voltage And Load Torque, Closed Loop Control Systems.

Induction Motor Drives: Review of Conventional Methods, Stator Voltage Control, Rotor Resistance Control, Slip Power Recovery, Static Kramer Drives And Static Scherbius Drive, V/F Control, Closed Loop Control, Introduction To Vector Control And Direct Torque Control Schemes, Special Machines: Brushless DC Motor, Switched Reluctance Motor, PMSM. Sensored and sensorless control of Induction motor and PM machines. Flux Switching machine, Introduction To The Relevant Converter Circuits, Introduction To Kinetic Energy Recovery Systems (KERS).

Simulation and Hardware experiments based on converter/ drive topologies relevant to topics.

TEXT BOOKS/ REFERENCES:

1.R. Krishnan, "Electric Motor Drives, Modeling , Analysis And Control", Prentice Hall, Nj, 2001.

2.Gopal K. Dubey. "Fundamentals Of Electrical Drives", Narosa Publishing House. 2001.

3.*Iqbal Hussain, "Electric And Hybrid Electric Vehicle's Design Fundamentals", Second Edition, CRC Press, 2010.*
4.*Muhammed H. Rashid, "Power Electronics, Circuits, Devices and Applications", Third Edition, Pearson Education Press, 2004.*
5.*Mehrdad Eshani, YiminGao and Ali Emadi, "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles", Second Edition, CRC Press 2009.*

19PR722SYSTEM ENGINEERING AND INTEGRATION 3-0-0-3

Overview of the systems engineering domain; definitions key to systems engineering; the system life cycle, and the product development life cycle. Phase gate approach to product development enabled by application of systems engineering principles. Concept Exploration and the four types of systems requirements that must be extracted from the customer's statement of want and needs. Dual nature of validation, and its differences from verification.

Requirement analysis, requirements development, and how these relate to planning for systems integration, verification and validation. Functional analysis, interface analysis, requirement allocation, traceability, and use of commercial tools to enable effective application of SE principles in an integrated team environment.

Development of a master compliance matrix, a test and evaluation master plan, and use of technical performance measures in defining system performance. Use of trade study methods for system definition. Applying these methods in concept exploration and system definition. Modeling, simulation and systems analysis enable analysis of alternatives in concept exploration. Applying specialty-engineering disciplines by the system engineer throughout the product development life cycle, and the system life cycle.

Gaining practical experience in the use of reliability, system safety and human factors engineering. Examining risk management concepts, techniques, and tools and their utility inthe concept exploration phase, as well as carry-over utility into the later phases of the product development life cycle.

Exploring the technical management responsibilities and functions of the systems engineer applicable to the entire system and product development life cycles. Examining the later stages of the product development life cycle after Concept Development and understand how knowledge development continues through the phases: preliminary design, detailed design, integration and test, system validation, full rate production. (Explore the ideas behind concurrent engineering, design for six sigma and total quality development as they apply to the systems engineering roles, responsibilities, and the development of high quality products in any market, industry or sector.

Course should be taught in view of electric vehicle as the system.

TEXT BOOK / REFERENCES:

1.*Benjamin S. Blanchard and Wolter J. Fabrycky, Systems Engineering and Analysis, 5th ed., Prentice Hall International Series in Industrial and Systems Engineering, (Upper Saddle River, NJ), 2006. ISBN-13: 978-0-13-221735-4.*

19PR723ELECTRIC DRIVES AND CONTROL 3-0-0-3

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: unifiedapproach 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 three phase to two phase and from rotating axes to stationary axes, invariance of power. Principle ofvector Control: vector controlled induction motor drive, basic principle, direct rotor fluxoriented vector control, estimation of rotor flux and torque, implementation with currentsource and voltage source inverters. Stator flux oriented vector control, indirect rotor fluxoriented vector control scheme, implementation, tuning. Vector control strategies forsynchronous motor. Introduction to sensor-less control, basic principle of direct torquecontrol, MRAS, PLC based control. Simulation and case studies on the above controltechniques.

TEXT BOOKS/ REFERENCES:

1. *R. Krishnan, "Electric Drives: Modelling, Analysis and Control", PHI, 2007.*
2. *G.K Dubey,"Fundamentals of Electrical Drives", Narosa publications 1995*
3. *Vedam Subramaniam, "Electric Drives: Concepts and Applications", Tata McGraw Hill,2011.*
4. *Bose B. K, "Modern Power Electronics and AC Drives", Pearson Education Asia, 2002.*
5. *N. K. De and P. K. Sen, "Electric Drives", PHI, New Delhi 2001.*
6. *M. D. Singh and K. B. Khanchandani, "Power Electronics", Tata McGraw Hill, 2008.*
7. *Joseph Vithayathil," Power Electronics, Principles and Applications", McGraw Hi Series,. 6 th.Reprint, 2013.*

19PR724CONTROL SYSTEM DESIGN 3-0-0-3

Control system design by root locus method: lag, lead, lag-lead compensators, control system design by frequency response: lag, lead, lag-lead compensators. PID controller design:Tuning algorithms for PID controllers, optimal PID tuning, anti-reset wind up, derivativekick, 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 forfull state feedback, design of servo systems. Observer design: Reduced order observer, designof regulator systems with observers. Computer aided designs. Simulations and case studies ofclassical 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.*

19PR725E-MOBILITY BUSINESS AND POLICIES 3-0-0-3

Introduction to India's passenger mobility sector- Current State of India's Public Transport System, Public Transport: Efficiently and Affordably Mobilizing Cities, Opportunities To Maintain And Ideally Increase The Utilization Of Public Transport In India, Expanding India's Definition Of Public Transport Through Data And New Business Models, India's Path Forward In Public Transport, Sharing and Mobility Services: Unlocking Economic Electrification- the

business case for shared, electric mobility services, Examples of Shared Mobility Services Active In Today's Global Marketplace- Ride-Hailing Services: Pooled Ride-Hailing Services: Vehicle Sharing: Peer-To-Peer Vehicle Sharing: Fixed-Route Commuter Services: Incentives to promote electric mobility and sharing: Parking and pick-up benefits: Road toll and road tax discount or exemption: Licensing and registration benefits, Congestion pricing: Low-emission zones: EV Charging Infrastructure: Powering EVs and Recharging 4 India's Electricity Sector: Considerations and Implications For India's Ev Charging Infrastructure Deployment Standards: EV standards-IEEE, IEC and SAE, Basics of EV charging, EV charging standards and infrastructure, SmartParks, V2G, G2V, V2B, V2H, renewable energy integration to EV charging infrastructure.

TEXT BOOK/REFERENCES:

1. *Emadi, A. (Ed.), Miller, J., Ehsani, M. (2003). Vehicular Electric Power Systems. Boca Raton: CRC Press.*
2. *Husain, I. (2010). Electric and Hybrid Vehicles. Boca Raton: CRC Press.*
3. *Larminie, James, and John Lowry. Electric Vehicle Technology Explained. John Wiley and Sons, 2012.*
4. *Tariq Muneer and Irene IllescasGarcía, 1 - The automobile, In Electric Vehicles: Prospects and Challenges, Elsevier, 2017, Pages 1-91*

19PR726 AUTOMOTIVE ELECTRONICS 3-0-0-3

Introduction to Electronic systems in Automotives – Sensors and Actuators for body electronics, power train and chassis systems. Body electronics domain- Automotive alarms, Lighting, Central locking and electric windows, Climatic Control, Driver information, Parking, etc. Power train and chassis control domain – Engine management , Transmission control, ABS, ESP, Traction Control, Active Suspension, passive safety, Adaptive Cruise Control, etc. Hardware implementation example of simple automotive systems using Sensors, Controller, Actuators etc. Battery- types and maintenance, Alternators in vehicles, Starting motor systems, Electrical circuits and wiring in vehicles, vehicle network and communication buses – Digital engine control systems, Introduction to automotive controllers, On-Board Diagnostics (OBD).

TEXT BOOKS/REFERENCES:

2. *Bosch,"Automotive Electrics and Automotive Electronics. System and components ,Networking and Hybrid drive", Fifth edition, Springer view 2014*
3. *Najamuz Zaman , " Automotive Electronics Design Fundamental'' first edition, Springer 2015.*
4. *Hillier's, "Fundamentals of Motor Vehicle Technology on Chassis and Body Electronics", Fifth Edition, Nelson Thrones, 2007.*
5. *William B. Ribbens, "Understanding Automotive Electronics" Sixth Edition, Elsevier Newnes, 2002*

19PR727AUTOMOTIVE CONTROL SYSTEMS 3-0-0 -3

Overview Of Control System: Modeling, Time/Frequency Response Analysis And Stability Analysis: PID , State Variable Analysis.

Model Based Diagnosis: Characteristics, Faults, Fault Modeling, Principles Of Model Based Diagnostics- Residual Generator Design, Residual Evaluation, Engineering Of Diagnosis Systems, Application Example. Vehicle Control Systems: ABS Control Systems- Torque Balance At Vehicle- Road Contact, Control Cycles Of The ABS System, ABS Cycle Detection; Control Of Yaw Dynamics- Deviation Of Simplified Control Law, Derivation Of Reference Values.

Road And Driver Models: Road Model- Requirements Of The Road Model, Definition Of The Course Path, Road Surface And Wind Strength; PID Driver Model; Hybrid Driver Model – Vehicle Control Tasks, Characteristics Of Human As A Controller, Information Handling, Complete Driver Model.

Simulation/case studies on relevant topics.

TEXT BOOKS/REFERENCES:

1. *Kiencke, Uwe and Nielsen, Lars, "Automotive Control Systems for Engine, Driveline and Vehicle", Springer, 2005*
2. *I.J Nagrath and M.Gopal, "Control Systems Engineering", Wiley Eastern Limited, New Delhi, 2008.*
3. *M.Gopal, "Modern Control System Theory", New Age International,2005.*
4. *Katsuhiko Ogata, "Modern Control Engineering", Fifth Edition, Prentice Hall, 2010.*

19PR728 VEHICLE DYNAMICS AND CONTROL 3-0-0-3

Introduction To Driver Assistance Systems, Active Stability Control, Ride Quality, Technologies For Addressing Traffic Congestion, Emissions And Fuel Economy; Lateral Vehicle Dynamics: Kinematic Models, Dynamic Bicycle Model, From Body Fixed To Global Coordinates: Lateral Vehicle Control: State Feedback, Steady State Analysis: Understanding Steady State Comering, The Output Feedback Problem, Compensator Design With Look Ahead Measurement; Longitudinal Vehicle Dynamics: Longitudinal Vehicle Model, Driveline Dynamics, Mean Value Engine Models

Longitudinal Vehicle Control: Introduction : Cruise Control ,Control System Architecture, Adaptive Cruise Control, Individual Vehicle Stability And String Stability, String Stability With Constant Spacing, String Stability With Constant Time Gap, Controller For Transitional Maneuvers, Automated Highway Systems, Longitudinal Control For Vehicle Platoons, String Stability With Inter- Vehicle Communication, Adaptive Controller For Unknown Vehicle Parameters.

Electronics Stability Control: Vehicle Model, Control Design For Differential Braking Based Systems, Control Design For Steer-By-Wire System, Independent All Wheel Drive Torque Control: Active Automotive Suspensions: H2 Optimal Control, LQR Formulation For Active Suspension Design, Analysis Of Trade-Offs Using Invariant Points, Performance Of The Sky-Hook Damping Controller, Control With Hydraulic Actuators; Semi-Active Automotive Suspensions: Theoretical Results: Optimal Semi-Active Suspensions, Interpretation Of The Optimal Semi-Active Control Law, Calculation Of Transfer Function Plots With Semi-Active Control Law; Rollover Prevention Control: Rollover Dynamics, Rollover Index And Active Rollover Prevention, Comparison Of Performance With Various Rollover Indices.

Lab Experiments Based On Simulation Tools.

TEXT BOOKS/REFERENCES:

1. *Thomas D. Gillespie, "Fundamentals of Vehicle Dynamics", SAE International, 2005.*
2. *R. Rajamani, "Vehicle Dynamics and Control", Second Edition, Springer Verlag, 2012.*
3. *Uwe Kiencke and Lars Nielsen, "Automotive Control Systems: For Engine Driveline, and Vehicle", Second edition, Springer, 2005.*
4. *John C Dixon, "Tyres, Suspension and handling", 2nd Revised Edition, SAE International, 1996.*
5. *Hans B. Pacejka, "Tyre and Vehicle Dynamics", Second Edition, Butterworth-Heinemann, 2006.*