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 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 various streams like Smartgrids, Electric Vehicles, Power System, Sustainable and Renewable Energy, Computational and Communication Technology Applications, Power Electronics and Control, and Embedded Systems. This programs aims to make students employable in various sectors of Power & Energy, Communication, Smartgrid, 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
21PR601	FC	Software Based Numerical Computation Methods	2-0-2	3
21PR605	SC	Smart Power Grids	3-0-2	4
21PR606	SC	Sustainable and Renewable Energy Technology	3-0-2	4
21PR604	FC	Power Electronic Converters for Smartgrids and Electric Vehicles	2-0-2	3
21PR603	SC	Electric Vehicle Technology	3-0-2	4
21PR602	FC	Digital Signal Controllers	3-0-2	4
21HU601		Amrita Values Program*		P/F
21HU602		Career Competency I*		P/F
		Credits		**22**

***** Non-credit course; **L-T-P**: Lecture- Tutorial- Practical Hours

SECOND SEMESTER

Course Code	Type	Course	L-T-P	Credit
21PR612	FC	Machine Learning, Deep Learning And Multi Agent Systems Applications In Smartgrid	3-0-2	4
21PR611	SC	Intelligence & Communication in Smartgrid	3-0-2	4
21PR613	SC	Vehicular Networks and communications	3-0-2	4
	E	Elective 1	3-0-0	3
	E	Elective 2	3-0-0	3
21PR681	P	Application Development lab	0-0-2	1
21HU603		Career Competency II	0-0-2	1
21RM614		Research Methodology		2
		Credits		**22**

THIRD SEMESTER

Course code	Type	Course	credit
21PR798	**P**	Dissertation I	**10**

FOURTH SEMESTER

Course code	Type	Course	credit
21PR799	**P**	Dissertation 2	**16**
		Total	**70**

LIST OF COURSES

Foundation Core (FC)

Course Code	Course	L – T – P	Credits
21PR601	Software Based Numerical Computation Methods	2-0-2	3
21PR604	Power Electronic Converters for Smartgrids and Electric Vehicles	2-0-2	3
21PR602	Digital Signal Controllers	3-0-2	4

Subject Core (SC)

Course Code	Course	L – T – P	Credits
21PR605	Smart Power Grid	3-0-2	4
21PR603	Electric Vehicle Technology	3-0-2	4
21PR606	Sustainable and Renewable Energy Technology	3-0-2	4
21PR612	Machine Learning, Deep Learning And Multi Agent Systems Applications In Smartgrid	3-0-2	4
21PR611	Intelligence & Communication in Smartgrid	3-0-2	4
21PR613	Vehicular Networks and communications	3-0-2	4

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
21PR631	Advanced Digital Signal Controllers and Applications	3-0-0	3
21PR632	Advanced Optimization Techniques for Power System Applications	3-0-0	3
21PR633	Bio- Energy Conversion	3-0-0	3
21PR634	Computational Intelligence for Power Applications	3-0-0	3
21PR635	Cyber Physical Systems	3-0-0	3
21PR636	Energy Conservation and Management	3-0-0	3
21PR637	Energy Storage Technology	3-0-0	3
21PR638	ICT enabled Power System Protection	3-0-0	3
21PR639	Mathematical Modelling of Energy Systems	3-0-0	3
21PR640	Power Plant Instrumentation	3-0-0	3
21PR641	Power System Planning, Operation And Control	3-0-0	3
21PR642	Solar Energy Utilisation	3-0-0	3

21PR643	Wind Energy Conversion Systems	3-0-0	3

ELECTIVES -II
(Subjects include areas from Automotive applications and Electric Vehicles)

Course Code	Course	L – T – P	Credits
21PR651	Advanced Power Electronics for Automotive Applications	3-0-0	3
21PR652	Automotive Control System	3-0-0	3
21PR653	Automotive Electronics	3-0-0	3
21PR654	Control System Design	3-0-0	3
21PR655	Electric Drives And Control	3-0-0	3
21PR656	E-mobility Business and policies	3-0-0	3
21PR657	System Engineering and Integration	3-0-0	3
21PR658	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
21PR681	Application Development lab	0-0-2	1
21PR798	Dissertation I		10
21PR799	Dissertation II		16

Program Outcomes

PO1: An ability to independently carry out research /investigation and development work to solve practical problems
PO2: An ability to write and present a substantial technical report/document
PO3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
PO4: Ability to use advanced techniques, skills and modern scientific and engineering tools for professional practice
PO5: Developing professional competence and leadership qualities with a harmonious blend of moral and ethical values

21PR601 SOFTWARE BASED NUMERICAL COMPUTATION METHODS 2-0-2-3

Course Outcome:

CO1	Demonstrate understanding of common numerical methods and how they are used to obtain approximate solutions to otherwise intractable mathematical problems.
CO2	Apply numerical methods to obtain approximate solutions to mathematical problems.
CO3	Derive numerical methods for various mathematical operations and tasks, such as interpolation, differentiation, integration, the solution of linear and nonlinear equations, and the solution of differential equations.
CO4	Analyse and evaluate the accuracy of common numerical methods.
CO5	Implement numerical methods in Matlab. Write efficient, well-documented Matlab code and present numerical results in an informative way.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	2	-	-	-	-
CO2	2	-	-	-	-
CO3	3	1	2	-	-
CO4	3	1	2	-	-
CO5	3	1	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 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", 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.*

21PR605 Smart Power Grid
3-0-2-4

Course Outcome:

CO1	To understand the concept of microgrids, and Smart Grids – need, structure its operation and various control strategies.
CO2	Familiarity with communication technologies, real time monitoring schemes and state of art Smart Grids technologies.
CO3	Familiarising the standards and power quality issues and improvement techniques in the smart grid.
CO4	To understand how all energy interactions including renewable sources, Plug-in electric vehicles and energy sharing with Grid happens.
CO5	Design and development of Smartgrid concepts in realizing systems for practical applications.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3: High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	1	2	2	1
CO2	3	1	3	1	1
CO3	2	1	3	2	1
CO4	3	2	1	1	1
CO5	2	1	3	1	1

Smart Grids: Review of power system operation in conventional and restructured system, Introduction to modern power systems: Evolution of microgrids and smartgrids; 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, Geographical Information System; Penetration of Clean Energy Technologies; Power electronics and power quality in Smart grid; power quality issues, IEEE/IEC standards, Power quality improvement techniques:
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.*
7. Arillaga, N.R.Watson and S.Chen, "Power System Quality Assessment", John Wiley & *Sons, England, 2000.*
8. Math J.Bollen, "Understanding Power Quality Problems-Voltage Sags and *Interruptions", John Wiley & Sons, New Jersey, 2000.*
9. Bhim Singh, Ambrish Chandra and Kamal Al-Haddad, "Power Quality: Problems and *mitigation Techniques", Wiley 2015.*
10. Enrique Acha and Manuel Madrigal,"Power Systems Harmonics-Computer Modeling*and Analysis", John Wiley and Sons Ltd., 2001.*

21PR606 SUSTAINABLE AND RENEWABLE ENERGY TECHNOLOGY
3-0-2-4

Course Outcome:

CO1	Impart insight to future energy systems and their significance
CO2	Awareness on international agreements/conventions on energy and sustainability
CO3	Understand the basic energy conversion technologies of renewable energy sources
CO4	Design and control of renewable energy sources in standalone and grid connected mode
CO5	Analyze the intermittency problem of RES and to realize the importance of energy storage system.
CO6	Realize the state of the Art in Power& Energy industry R&D

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3: High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	2	2	-	-	-
CO2	2	2	-	-	-
CO3	3	1	1	2	-
CO4	3	1	1	2	1
CO5	3	2	2	2	1
CO6	3	1	-	-	-

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*

21PR604 POWER ELECTRONIC CONVERTERS FOR SMARTGRIDS AND ELECTRIC VEHICLES 2-0-2- 3

Course Outcome:

CO1	Fundamental concepts of electric power conversion
CO2	Analyse the behaviour of power converters under steady state conditions
CO3	Understanding the control techniques of power converters
CO4	Design and development of power converter circuits, magnetic and protection systems for field applications
CO5	Study the performance of power converter using simulation tools
CO6	Implementation of concepts in realizing systems for practical applications

<u>Course Articulation Matrix: Correlation level [1: low, 2: medium, 3: High</u>

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1			2		
CO2	2	1	3		
CO3	1	1	3		
CO4	2	1	3	2	
CO5	2	1	3	2	
CO6	3	3	3	2	3

Introduction to converters for DGs in Smart Grid, DC-DC converters: Buck, boost, buck-boost,. Forward, fly-back and 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. *B K Bose, "Modern Power Electronics and AC Drives"Pearson publications,1st edition*
4. *R. Erickson, D. Maksimovic, Fundamentals of Power Electronics, Springer 2001*
5. *Ehab H E Bayoumi,"Power electronics in smart grid distribution power systems: A review"-International Journal of Industrial Electronics*
6. *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*
7. *Selected transactions on Electric vehicles and Smartgrids*

21PR603 ELECTRIC VEHICLE TECHNOLOGY
3-0-2-4

Course Outcome:

CO1	Develop ideas on basic schemes of electric vehicles and hybrid electric vehicles.
CO2	Choose a suitable drive scheme for electric and hybrid vehicle depending on resources.
CO3	Select proper energy storage and associated power electronic systems for electric vehicle applications
CO4	Identify various communication protocols and technologies used in vehicle networks
CO5	Study the fundamentals of various vehicular communication technologies
CO6	Familiarize and work with advanced simulation software and hardware technologies.

<u>Course Articulation Matrix: Correlation level [1: low, 2: medium, 3: High</u>

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	2	-	3	1	-
CO2	2	-	3	2	-
CO3	2	-	3	2	-
CO4	2	-	3	2	-
CO5	2	-	3	2	-

CO6	2	2	3	2	2

Review of Conventional Vehicle: Introduction to Hybrid Electric Vehicles: Types of EVs, Vehicle Dynamics, Modeling of drive train, Hybrid Electric Drive-train, Energy consumption Concept of Hybrid Electric Drive Trains, Architecture of Hybrid Electric Drive Trains, Series Hybrid Electric Drive Trains, Parallel hybrid electric drive trains, EV Motors and Controllers: 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, super capacitor, and fuel cell based energy storage system and their analysis, Hybridization of different energy storage systems. Energy Management Strategies, EV charging standards, V2G, G2V, V2B, V2H. Sizing the drive system: Design of Hybrid, Plug-in and Fuel cell Electric Vehicles, Introduction to Automotive networking and communication, Introduction to AUTomotive Open System Architecture (AUTOSAR). 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*

21PR602 DIGITAL SIGNAL CONTROLLERS
3-0-2-4

Course Outcome:

CO1	Understand architecture of Digital Signal Controllers
CO2	Selection of Microprocessors/Microcontrollers/Digital Signal Controllers based on application
CO3	Familiarization and use of programming environment of Digital Signal controllers
CO4	Study on various peripherals associated with digital signal controllers.
CO5	Application development using digital signal controller.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3: High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	2			2	
CO2	1		1	3	
CO3			1	3	
CO4	1		1		
CO5	3	2	2	2	2

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

21PR612MACHINE LEARNING, DEEP LEARNING AND MULTI AGENT SYSTEMS APPLICATIONS IN SMARTGRID 3-0-2-4

Course Outcome:

CO1	Understand the concepts of supervised and unsupervised machine learning algorithms
CO2	Familiarizing the artificial neural networks and deep learning networks
CO3	Familiarizing different types of agents, formation of expert systems and agents communication languages
CO4	To apply machine learning, deep learning and multi agent systems in Smartgrids and electric vehicles

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3: High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	1	2		
CO2	3	1	2		
CO3	3	1	3		
CO4	3	1	3	3	1

Introduction to machine learning, statistics, data types, learning methods, regression analysis; Decision tree; Support Vector Machines-Kernel function; Clustering algorithm: k-means clustering; Neural networks-feed forward neural networks, back propagation algorithm, Introduction to deep learning, deep learning architectures-reinforced learning; Machine and deep learning with Python.
Intelligent Agents –Autonomy, Structure of Intelligent Agents- Agent programs-Goal-based agent-Utility-based agents, Environments, Problem Solving Agents, Formulating Problems-Knowledge and problem types- Well-defined problems and solutions-Measuring problem-solving performance-Choosing states and actions-Example Problems; Agents and Objects- Agents and Expert Systems-Agents as Intentional Systems-Abstract Architectures for Intelligent Agents; Agent-Oriented Programming; Reactive and Hybrid Agents -Agent Communication Languages -The FIPA agent communication languages –The JADE Platform.

Case study: Machine & deep learning applications in EV charging behavior analysis, fault detection in smart grid, optimum power scheduling; Multi-Agent Based Energy Management System for Electric Vehicles, aspects of failure analysis associated with energy storage systems etc.
Case study/Simulation/Hardware experiments.

TEXT BOOK/REFERENCES

1. *Christopher Bishop, "Pattern Recognition and Machine Learning",Second edition Springer New York, 2016.*
2. *Andreas C. Müller, and Sarah Guido, "Introduction to Machine Learning with Python" O'Reilly Media publihers, October 2016.*
3. *Valentino Zocca, GianmarioSpacagna, Daniel Slater, Peter Roelants, "Python Deep Learning" Packt Publishing, April 2017.*
4. *Michael Wooldridge "An Introduction to Multiagent Systems" JOHN WILEY & SONS, LTD*
5. *Stuart J. Russell and Peter Norvig , "Artificial Intelligence A Modern Approach" Prentice Hall, Englewood Cliffs, New Jersey.*
6. *Fabio Luigi Bellifemine, Giovanni Caire, Dominic Greenwood, "Developing Multi-Agent Systems with JADE" JOHN WILEY & SONS, LTD*
7. *Selected transactions on applications of machine learning, deep learning and multi agent systems in Electric vehicles and Smartgrids*

21PR611 INTELLIGENCE & COMMUNICATION IN SMART GRID
3-0-2-4

Course Outcome:

CO1	Familiarizing the network layered architecture.
CO2	Familiarity with Protocols and standards for data and communication in smart grid.
CO3	Familiarizing the Spectrum sensing techniques.
CO4	Familiarizing the Smart grid Data Analytics
CO5	Design and development of communication and intelligences concepts in realizing smart grid

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3: High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	1	1	2	1	
CO2	2	2	2	2	
CO3	3	2	2	3	
CO4	3	3	3	3	
CO5	3	3	3	3	

Need of intelligence and communication in Smart Grid, Case Study on Postmortem Analysis of Blackouts Drivers Toward the Smart Grid; Basics of Digital Data Communication, NETWORK layered ARCHITECTURE: OSI layer architecture , TCP architecture, Approaches for spectrum sensing and communications in smart grid: Cognitive radio (CR):Spectrum sensing methods, Cooperative Spectrum Sensing; Cooperative communications; compressive sensing applications in smartgrid; Networked control systems- Time driven, Event driven feedback schemes. Protocols and standards for information exchange; wired and wireless communication protocols for smartgrid. Data Analytics: Application of Big Data in Smart Grids - Intelligent Sensing, Data Preprocessing; Introduction to Machine Learning Techniques in Smartgrid; Artificial Neural Network and Deep Learning Applications in smart grid. Time Series Forecasting Techniques for smartgrid, Optimisation Applications in smartgrid. IoT architecture, IoT protocols – MQTT, COAP, and Web sockets with associated applications; IoT in Energy Sector- Internet of Energy, IoE.
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. *Kaveth Pahlavan. K. and Prashanth Krishnamurthy, "Principles of Wireless Networks", Prentice Hall of India, 2006.*
4. *Bart Baesens"Analytics in a Big data world" Wiley Publications,2004.*
5. *Toward Intelligent Machine-to-Machine Communications in Smart Grid. Communications Magazine, IEEE. 49. 60 - 65. 10.1109/MCOM.2011.5741147,2011.*

21PR613 VEHICULAR NETWORKS AND COMMUNICATIONS
3-0-2-4

Course Outcome:

CO1	Understand basics of analog and digital communication technologies.
CO2	To learn intra vehicular communication systems.
CO3	To learn and use vehicular communication protocols and standards.
CO4	Understand Inter vehicle communication systems.
CO5	Implement body electronic functionalities using controllers.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3: High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	1	-	-	2	-
CO2	1	-	1	3	-
CO3	-	-	1	3	-
CO4	1	-	1	2	-
CO5	1	1	3	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. AUTomotive Open System Architecture(AUTOSAR)

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.

Intelligent controller's communications protocols- Open Smart Charging Protocol- ISO 15118 protocol, ISO 15118 - IEC 63110, IEC61851-1, IEC61850-90-8, IEEE2030-5 and other advanced protocols used in smart grid to EV's

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.*

21PR681 APPLICATION DEVELOPMENT LAB
0-0-2-1

Course Outcome:

CO1	Familiarize simulation tools like MATLAB IDE, SIMULINK, ETAP, LABVIEW, PSCAD etc.
CO2	Lab training in ICs and kits
CO3	Acquire knowledge to write a technical paper
CO4	Ability to implement a research idea using simulation tools

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3: High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	3	2	3
CO2	3	3	3	2	1
CO3	3	2	3	1	1
CO4	3	2	3	1	1

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

21RM614 RESEARCH METHODOLOGY
2-0-0-2

Course Outcome

CO1	Introduction about research
CO2	Problem Formulation
CO3	Experimental research

CO4	Preparation for research and dissertation
CO5	Intellectual property rights

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	2	2	1	1	1
CO2	2	3	3	2	2
CO3	2	2	3	2	1
CO4	2	2	1	1	1
CO5	2	2	2	1	1

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; 6th edition July 2012*

21PR637 ENERGY STORAGE TECHNOLOGY 3-0-0-3

Course Outcome

CO1	Understanding the importance of the energy storage technology in power system
CO2	To study and Analyse the function of each storage technology, its characteristics
CO3	To explore the energy storage applications in Renewable energy systems, Electric vehicles and in Smartgrid.
CO4	To introduce the modelling and simulation of energy storage devices for energy management

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1		2	1		
CO2	1	2			
CO3	2	2	2		
CO4		1	1	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.
Smart Grid and Electric Vehicle Storage Technology: Micro-grid/Smart Grid with SPV, Wind Energy, Fuel cell, Hydrogen and Battery Energy Storage with BMS, Battery SCADA, Hybrid Energy storage systems: configurations and applications, Smart Home. Improved Battery Technologies for Electric Vehicle- commercialized battery technologies- Lead acid, LFP, LCO, Li-Polymer, Ni-MH, Ni-Cd and ICRFB advanced battery technologies- NMC111, NMC422, NMC532, NMC622, NMC811,NCA,LMO batteries and other advanced batteries for EV's.

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*

21PR638 ICT ENABLED POWER SYSTEM PROTECTION
3-0-0-3

Course Outcome

CO1	Develop and analyze typical power systems and their associated protection systems
CO2	Operational principles and types of electrical protection
CO3	Microprocessor based design of different types of relay
CO4	Protection coordination and architecture
CO5	Design and control of protection schemes using ICT

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	2	-	3	1	-
CO2	2	-	3	1	-
CO3	2	1	3	1	-
CO4	2	1	3	1	-
CO5	2	1	3	1	1

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 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.*

21PR631 ADVANCED DIGITAL SIGNAL CONTROLLERS AND APPLICATIONS 3-0-0-3

Course Outcome

CO1	Knowledge and understanding of DSP basic concepts
CO2	Knowledge and understanding of fundamental filtering algorithms
CO3	Knowledge and understanding of micro controllers as DSP computing platforms
CO4	Knowledge and understanding of software programming basics and principles
CO5	Intellectual ability to use different design methods to achieve better results
CO6	Practical ability to implement DSP algorithms and design methods on 8 bit micro controllers.

<u>Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High</u>

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	1	2	2	1
CO2	3	1	2	2	1
CO3	3	1	2	2	1
CO4	3	1	2	2	1
CO5	3	1	2	2	1
CO6	3	1	2	2	1

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*

21PR639 MATHEMATICAL MODELLING OF ENERGY SYSTEMS 3-0-0-3

Course Outcome

CO1	To understand the need for mathematical models and various model examples.
CO2	To study various quantitative techniques for model identification and to solve practical problems.
CO3	To formulate constrained and unconstrained optimization problems both linear and nonlinear and to solve practical problems.
CO4	To deal with uncertainty and to develop various energy economy models.
CO5	To study solution techniques for differential equations.
CO6	To apply various numerical methods and optimization techniques in energy systems namely power flow formulation, economic load dispatch, transient analysis, etc.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	1		1		
CO2	2		2		
CO3	2		2		
CO4	2		2		
CO5	2				
CO6	2		3	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.*

21PR635 CYBER PHYSICAL SYSTEMS
3-0-0-3

Course Outcome

CO1	To understand about cyber physical systems
CO2	To understand about controller design for the systems
CO3	To study about advanced techniques for analysis of cyber physical systems
CO4	Acquire knowledge about softwares for simulation of cyber physical systems

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	1	1	1
CO2	2	2	2	1	1
CO3	2	2	2	1	1
CO4	3	1	2	2	1

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 : Flow pipe construction using Flow star, Space X 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*

21PR636 ENERGY CONSERVATION AND MANAGEMENT
3-0-0-3

Course Outcome:

CO1	To study general principles of energy management and energy management planning, policies
CO2	To study the energy auditing methods, instruments and preparation of auditing report
CO3	To study various thermal energy saving methods and improving techniques
CO4	To study Management of electrical load and lighting
CO5	To impart the computer aided tools for energy management, energy efficiency policy initiatives.
CO6	To Analyse the energy economic analysis methods and tools used

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3: High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	2	2	1	1	1
CO2	3	2	2	1	1
CO3	2	2	2	1	1
CO4	3	2	2	2	2
CO5	2	2	2	1	1
CO6	2	2	2	1	1

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, 2003.*
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*

21PR642 SOLAR ENERGY UTILISATION

3-0-0-3

Course Outcome:

CO1	Understanding the importance of the solar energy in the current energy scenario and to analyse the behaviour of solar radiation, its availability and various solar radiation measurement techniques
CO2	To study the different types of solar cell technologies, their manufacturing technologies, Modelling methods etc.
CO3	To design a standalone, grid tie and hybrid solar PV systems and its associated components and conducting its feasibility through cost analysis.
CO4	To study the features of different MPPT techniques, solar tracking systems, solar energy forecasting and its application in solar power system.
CO5	Study and design of solar thermal systems and calculation of its energy output.

<u>Course Articulation Matrix: Correlation level [1: low, 2: medium, 3: High</u>

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1			1		
CO2	1		1	1	
CO3	2		2	1	
CO4	3		3	2	1
CO5	1		1		

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. *AlirezaKhaligh, Omer C. Onar "Energy Harvesting: Solar, Wind, and Ocean Energy Conversion Systems" Taylor and Francis CRC press, 2010*

21PR643 WIND ENERGY CONVERSION SYSTEMS
3-0-0-3

Course Outcome:

CO1	To Impart knowledge about wind energy conversion systems, turbine development state of art and trends in development, wind resource assessment.
CO2	To study about Wind turbine types, turbine loads, components, design aspects and storage technologies..
CO3	Learn about wind energy systems integration to electrical networks.
CO4	Discuss about the possibilities of smart applications in wind energy systems.
CO5	Understand about the financial aspects in design, installation, payback time etc.

<u>Course Articulation Matrix: Correlation level [1: low, 2: medium, 3: High</u>

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	3	1	1
CO2	3	2	3	2	1
CO3	3	2	3	2	1
CO4	2	2	3	1	1
CO5	3	2	3	1	1

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*

21PR640 POWER PLANT INSTRUMENTATION
3-0-0-3

Course Outcome

CO1	Estimate the energy flow using Sankey diagram in various parts of power plants
CO2	Illustrate the operation and layout of various power plant
CO3	Describe the different process and equipment associated with power plant.
CO4	Determine the behaviour of Boiler/Turbine instrumentation and its control
CO5	Development of automation for power plants.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	3	3	1	1
CO2	3	2	1	1	1
CO3	3	1		1	1
CO4	3	3		1	1
CO5	3	3	2	1	1

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).*

21PR634 COMPUTATIONAL INTELLIGENCE FOR POWER APPLICATION 3-0-0-3

Course Outcome

CO1	To understand the need for computational intelligence/expert systems.
CO2	Design and implementation of knowledge based experts system-fuzzy expert system for real world problem solving
CO3	Design and implementation of ANN and various NN architectures and learning algorithms for real world problem solving
CO4	Design and implementation of evolutionary computation techniques-GA and fitness formulation for real world problem solving
CO5	To apply combination of knowledge representation, evolutionary computation, and machine learning techniques to real-world problems
CO6	Application of computational intelligence in monitoring, control, protection, and optimization of power systems.

<u>Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High</u>

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	2	-	3	1	-
CO2	2	1	3	2	-
CO3	2	1	3	2	-
CO4	2	1	3	2	-
CO5	2	-	3	2	-
CO6	2	1	3	2	-

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, Un-supervised 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. *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*

21PR633 BIO-ENERGY CONVERSION
3-0-0-3

Course Outcome

CO1	To Study the basics and principles of bio energy conversion methods
CO2	To understand the concept of biomass usage for electricity generation
CO3	To Study the biogas production methods and storage
CO4	To study various types of algae and its usage for oil production and electricity generation

<u>Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High</u>

PO / CO	PO1	PO2	PO3	PO4	PO5

CO1	1	1	1		
CO2	2	1	3		
CO3	2	1	2		
CO4	2	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.

21PR641 POWER SYSTEM PLANNING, OPERATION AND CONTROL
3-0-0-3

Course Outcome

CO1	Realize the significance of power system planning by considering the present and future aspects
CO2	Realize the economic operation of thermal units and/or hydro units including various system constraints and the importance of interconnected operation various interchange policies of power system.
CO3	Realize the significance of state estimation.
CO4	Analyze Automatic Generation control and Voltage Control loops in power systems by considering the need of maintaining nominal frequency and voltage.
CO5	Evaluate and analyze the performance of the system using modern software tools

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	-	-	3	-	1
CO2	2	1	3	-	-

CO3	1	1	3	-	-
CO4	2	1	3	-	-
CO5	2	2	2	3	2

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. 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. 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.*

21PR632 Advanced Optimization Techniques for Power System Applications 3-0-0-3

Course Outcome

CO1	To understand various classical optimization techniques and the need for evolutionary optimization techniques
CO2	To understand and apply nature inspired optimization algorithms for solving practical problems.
CO3	To formulate multi objective optimization problems using nature inspired algorithms.
CO4	Acquire knowledge about software's for simulation of various optimization algorithms with application in power systems.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	2		2		
CO2	3		3		
CO3	2		2		
CO4	3	1	3	3	

Definition-Classification of optimization problems-Unconstrained and Constrained optimization Optimality conditions-Classical Optimization techniques (Linear and non-linear programming, Quadratic programming, Mixed integer programming)-Intelligent Search methods (Optimization neural network, Evolutionary algorithms, Tabu search, Particle swarm optimization, Application of fuzzy set theory).

Evolution in nature-Fundamentals of Evolutionary algorithms-Working Principles of Genetic Algorithm- Evolutionary Strategy and Evolutionary Programming (EP) -Genetic Operators-Selection, Crossover and Mutation-Issues in GA implementation- GA based Economic Dispatch solution Fuzzy Economic Dispatch including losses- Tabu search algorithm for unit commitment problem-GA for unit commitment-GA based Optimal power flow- GA based state estimation.

Particle Swarm Optimization -Fundamental principle-Velocity Updating-Advanced operators-Parameter selection- Binary, discrete and combinatorial PSO-Implementation issues-Convergence issues- Advanced Optimization Methods - Simulated annealing algorithm-Tabu search algorithm-SA and TS for unit commitment-Ant colony optimization- Bacteria Foraging optimization Multi Objective Optimization- Concept of pareto optimality-Conventional approaches for MOOP-Multi objective GA-Fitness assignment-Sharing function-Economic Emission dispatch using MOGA-

TEXT BOOKS/ REFERENCES:

1. D.P.Kothari and J.S.Dhillon, “Power System Optimization”, 2ndEdition, PHI learning private limited, 2010.
2. Kalyanmoy Deb, “Multi objective optimization using Evolutionary Algorithms” , John Wiley and Sons, 2008.
3. Kalyanmoy Deb, “Optimization for Engineering Design”,Prentice hall of India first edition,1988.
4. Carlos A.Coello, Gary B. Lamont, David A.Van Veldhuizen, “Evolutionary Algorithms for solving Multi Objective Problems”, 2ndEdition, Springer, 2007.
5. Soliman Abdel Hady,AbdelAal Hassan Mantawy, “Modern optimization techniques with applications in Electric Power Systems” ,Springer,2012.
6. Jizhong Zhu,” Optimization of power system operation”,John Wiley and sons Inc publication,2009.
7. KwangY.Lee, Mohammed A. El Sharkawi, “Modern heuristic optimization techniques”, John Wiley and Sons,2008.

21PR651 ADVANCED POWER ELECTRONICS FOR AUTOMOTIVE APPLICATIONS 3-0-0-3

Course Outcome

CO1	Understand the evolution and development of electrical distribution systems in automobiles.
CO2	Choose and design power converter topologies for vehicle traction systems and power supply units of automotive electronic sensors and circuits

CO3	To develop knowhow of braking and propulsion using DC and AC drive systems which operates in fluctuating source voltage environment
CO4	Investigate operation of traction control units for Induction and special electric machines.
CO5	To develop basic understanding of various kinetic energy recovery systems

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	1		2		
CO2	2		3	1	
CO3	2		3	1	
CO4	1		2		
CO5	1		1		

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 sensor less 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.*

21PR657 SYSTEM ENGINEERING AND INTEGRATION
3-0-0-3

Course Outcome

CO1	Develop a comprehensive knowledge of the key aspects of systems engineering.
CO2	Apply systems engineering practices and methods to engineered systems.
CO3	Develop and create objectives, requirements, architectures, specifications, verifications, and tests for an engineered system.
CO4	Frame systems architecture as a series of decisions, which can be actively sorted, managed, and optimized to suit the organization's needs.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	1		1		1
CO2	2		2	1	
CO3	2		1	3	
CO4	1		1	1	1

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 in the 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, <u>Systems Engineering and Analysis</u>, 5th ed., Prentice Hall International Series in Industrial and Systems Engineering, (Upper Saddle River, NJ), 2006. ISBN-13: 978-0-13-221735-4.*

21PR655 ELECTRICAL DRIVES AND CONTROL 3-0-0-3

Course Outcome

CO1	Review of the basic characteristics of a controllable drive and select a suitable motor rating for a particular drive application
CO2	Formulate the mathematical model of DC and AC Machines for transient and steady state conditions and analyse the performance.
CO3	Apply reference frame theory to AC machines.
CO4	Illustrate suitable control techniques for DC & AC drives.
CO5	Investigate the vector control techniques for AC drives.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	3	1	1
CO2	3	2	2	3	
CO3	3	1	2	1	
CO4	3	3	3	2	
CO5	3	2	3	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 three phase to two phase and from rotating axes to stationary axes, invariance of power. Principle of vector Control: vector controlled induction motor drive, basic principle, direct rotor flux oriented vector control, estimation of rotor flux and torque, implementation with current source and voltage source inverters. Stator flux oriented vector control, indirect rotor flux oriented vector control scheme, implementation, tuning. Vector control strategies for synchronous motor. Introduction to sensor-less control, basic principle of direct torque control, MRAS, PLC based control. Simulation and case studies on the above control techniques.

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. *G.K Dubey, "Power Semiconductor Controlled Drives", Prentice-Hall International, Inc.*

4. *VedamSubramaniam, “Electric Drives: Concepts and Applications”, Tata McGraw Hill,2011.*
5. *Bose B. K, “Modern Power Electronics and AC Drives”, Pearson Education Asia, 2002.*
6. *N. K. De and P. K. Sen, “Electric Drives”, PHI, New Delhi 2001.*
7. *M. D. Singh and K. B. Khanchandani, “Power Electronics”, Tata McGraw Hill, 2008.*
8. *Joseph Vithayathil," Power Electronics, Principles and Applications", McGraw Hi Series,. 6th Reprint, 2013.*

21PR654 CONTROL SYSTEM DESIGN 3-0-0-3

Course Outcome

CO1	To design a controller/compensator using time and frequency domain techniques
CO2	To understand different structural configurations of PID controllers and the tuning methods
CO3	Acquire knowledge to design observers and controllers for linear systems so as to be able to implement the methodology for practical control systems.
CO4	Acquire knowledge to develop and utilize modern software tools for analysis and design of linear continuous system.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	1	3	3	2
CO2	3	1	2	2	1
CO3	3	1	3	3	1
CO4	3	1	3	3	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.*

21PR656 E-MOBILITY BUSINESS AND POLICIES 3-0-0-3

Course Outcome

CO1	To develop ability to analyse the need for urban mobility and efficient public transportation in India
CO2	To understand various electric mobility and shared mobility services and its business
CO3	To introduce the incentives to promote electric mobility and sharing
CO4	To understand the basics and deployment standards of EV charging stations and renewable energy integration to charging station
CO5	To understand the concept of smart park, smart cities, and role of EV’s in India’s electricity sector.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	1		1		
CO2	2		2		
CO3	1		1		
CO4	3		2		
CO5	2		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, Smart Parks, 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*

21PR653 AUTOMOTIVE ELECTRONICS 3-0-0-3

Course Outcome

CO1	Analyze the vehicle electronic circuits.
CO2	Understand the working of sensors and ECU.
CO3	Understand the need of safety in automobiles.
CO4	Outline the working of batteries, starting systems, charging systems, ignition systems and auxiliaries.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	-	-	-	-
CO2	3	3	3	2	-
CO3	3	3	3	2	1
CO4	3	3	3	1	-

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:

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

21PR652 AUTOMOTIVE CONTROL SYSTEMS
3-0-0 -3

Course Outcome

CO1	To provide a basic understanding of the concepts and techniques involved in designing control schemes for automotive systems
CO2	Critically evaluate an automotive control system and be able to propose a functional safety strategy, appropriate for its integration within a productionized vehicle system
CO3	Model and design controllers for automotive traction, braking, steering and suspension.
CO4	Analyze automotive systems for their stability and performance

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	1		2		
CO2	2		2		
CO3	3		2	1	
CO4	2		2	1	

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.*

21PR658 VEHICLE DYNAMICS AND CONTROL
3-0-0-3

Course Outcome

CO1	To give an introduction to Driver Assistance Systems
CO2	To understand the different models of lateral and longitudinal vehicle dynamics
CO3	To understand and design different models and control methods to improve the stability of vehicular systems.
CO4	To develop ability to design vehicle dynamics control systems using electronics.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	1		1		
CO2	2		3	1	
CO3	2		3	1	
CO4	3		3	1	

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.*