Semester VII

Wireless Power Transfer

Power Protection Laboratory

Course code: L.T.P

Rationale:

Course Outcome:

Topics:

- Determine the ABCD parameters of a transmission lines.
- Study of electromechanical type over current relay & over voltage relay
- Fault location of Under Ground Cable by Varley Loop Test
- Develop software programs for analysis of power systems

Textbook(s):

1. Modern Power System Analysis, I. J. Nagrath, D. P. Kothari, Tata McGraw-Hill Publishing Company Ltd, New Delhi, 4th Edition 2013.

2. Electrical Power System, C.L. Wadhwa, New Age International (P) Limited, Publishers, 2010.

Reference Book(s):

1. Power system analysis by Hadi Sadat Tata McGraw Hill.

2. Fundamentals of Power System Protection", Y. G. Paithankar, S. R. Bhide, nd edition, Prentice Hall of India Private Limited, New Delhi, 2011

3. A Text Book on Power System Engineering, A. Chakrabarti, M.L. Soni, P.V. Gupta and U.S. Bhatnagar, Dhanpat Rai and Co., Reprint 2012

Professional Elective-V

Principles of Harmonics Elimination and Application

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

Introduction

Linear and nonlinear loads, introduction to different power quality issues, causes and their effects, definition-

Unit-II

RMS value, average power, True power factor, K-factor, Phase Shift, Phase Sequence, Standards-factors

Unit-III

influencing the development of standards, existing harmonic standards (IEC, IEEE), general harmonics

Unit-IV

indices(THD & TDD).

Causes of Harmonics

Transformer magnetizationnonlinearities,rotating machine harmonics, power electronics loads such as

line-commutated converters- typical current waveforms and THD, switched mode power supplies-typical

current waveforms and THD, harmonic spectrums of television receivers, microwaves, personal

computers and printers, non-characteristic and inter-harmonics

Effect of Harmonics

Unit-V

Harmonic resonance in power systems, nuisance tripping, blown capacitor fuses and capacitor cells,

degradation of internal capacitance, effects of harmonics on rotating machines, motor and torque pulsations,

overheating, overloading neutrals, effect of harmonics on static power plant, effect of harmonics on

consumer equipment, telephone interference.

Harmonic Measurement Methods

Harmonic monitoring, field measurements using voltage and current transducers, concept of harmonic

phase angle displacement, harmonic symmetrical components, harmonic instrumentation.

Harmonics Mitigation Techniques

Passive filtering techniques, classification of passive filters, passive filter design methods, tuned filters,damped filters, analysis of different analytical techniques: FFT and DFT, concept of multi pulse converter, PWM for harmonic elimination.

Text Book

1. Arrillaga J. and Waston N.R., “Power System harmonics”, Wiley Second Edition, U.S.A., .

2. Prof. Mack Grady, “Understanding Power System harmonics”; Department of Electrical & Computer Engineering University of Texas at Austin, U.S.A., 2012.

Reference Books

1. “Power Systems Harmonics” by George J. Wakileh, Springer, .

2. F. Z. Peng, “Harmonic sources and filtering approaches,” IEEE Ind. Appl. Mag., vol. 7, pp. 18–25, 2001.

3. Power Electronics Converter Harmonics: Multipulse Methods for Clean Power, Derek A. Paice, Wiley-IEEE Press, 1999.

Polyphase Systems and Component –Transformations

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

Balanced poly-phase circuits: Generation of poly-phase voltages, Phase sequence, three-phase 3-wire and 4-wire systems, wye and delta connections, n -phase star and mesh, power calculations in balanced systems, harmonics in wye- and delta-systems. Unbalanced poly-phase circuits: unbalanced loads, wye-wye system with and without neutral connections, neutral shift, wye-delta system, phase-sequence effects, extensions to non-sinusoidal behaviour. Introduction to symmetrical components: A brief historical review, application of the method. Calculation of unbalance faults. Multiphase systems: Resolution of multiphase systems into symmetrical components, 2-phase and 4-phase systems, Irregular systems.

1. Edith Clarke, Circuit Analysis of AC Power Systems – Volumes I and II, John Wiley and Sons, 1950.

2. C. F. Wagner, R. D. Evans. Symmetrical Components, McGraw-Hill, 1933.

3. J. L. Blackburn, Symmetrical Components for Power System Engineering, Marcel-Dekker,1993.

Smart Grid

Course code: L.T.P

Rationale:

Course Outcome:

CO1	Know the different elements of smart grid.
CO2	Demonstrate on Smart Grid Architecture.
CO3	Describe in Synchro Phasor Measurement Unit.
CO4	Understand the wide area monitoring system of smart grid.
CO5	Solve the load flow analysis in micro grid.
CO6	Control of the voltage and reactive power in smart grid.

Unit-I

Introduction to Smart Grid

Definition of smart grid, Components and architecture of smart grid design, Review of the proposed architectures for smart grid, The fundamental components of smart grid designs, Transmission automation, Distribution automation, Renewable integration.

Unit-I

Tools and Techniques for Smart Grid

Unit-II

Synchro Phasor Measurement Units (PMUs), Computational intelligence techniques, Distribution Generation Technologies

Unit-III

Communication Technologies and Smart Grid

Computational techniques, Static and dynamic optimization techniques, Introduction to communication technology, Evolutionary algorithms, Artificial intelligence techniques.

Unit-IV

Control of Smart Power Grid System

Unit-V

Load Frequency Control (LFC) in micro grid system, Voltage control in micro grid system, Reactive power control in smart grid, Case studies and test beds for the smart grids.

Text Book

1. James Momoh, “SMART GRID, Fundamentals of Design and Analysis” IEEE press, .

2. A. G. Phadke and J. S. Thorp, “Synchronized Phasor Measurements and their Applications”, Springer

Edition, 2010

Reference Books

1. Gil Masters, "Renewable and Efficient Electric Power System", Wiley–IEEE Press, 2004.

2. T. Ackermann, "Wind Power in Power Systems", Hoboken, NJ, USA, John Wiley, 2005.

3. Clark W Gellings P.E. "The Smart Grid enabling energy efficiency and demand response", CRC

Press, 2013.

4. Stuart Borlase, "Smart Grids, Infrastructure, Technology and Solutions", CRC Press, 2013.

Energy Management and SCADA

Course code: **L.T.P**

Rationale:

Course Outcome:

CO1	Know recent developments in Energy management System.
CO2	Understand economic load dispatch and unit commitment.
CO3	Analyze the economic aspect of energy production.
CO4	: Demonstrate the knowledge of energy management to existing system.
CO5	Understand optimization and control of power systems.
CO6	Describe SCADA system.

Unit-I

Introduction to Energy Management

Energy Management Centers and Their Functions, Architectures, Characteristics of Power Generating Units and Economic Dispatch, Unit Commitment (Spinning Reserve, Thermal, Hydro and Fuel Constraints), Solution techniques of Unit Commitment, Generation Scheduling with Limited Energy, Energy management system.

Unit-II

Economic Aspect

Energy Production Cost – Cost Models, Budgeting and Planning, Practical Considerations, Interchange Evaluation for Regional Operations, Types of Interchanges.

Unit-III

SCADA System

Introduction to Supervisory Control and Data Acquisition, SCADA Functional requirements and Components, General features, Functions and Applications, Benefits, Configurations of SCADA, RTU(Remote Terminal Units) Connections, Power Systems SCADA and SCADA in Power System Automation.

Unit-IV

Text Book

1. Wood, A. J and Wollenberg, B. F, & sheble B.G.“Power Generation Operation and Control”, nd

Edition John Wiley and Sons, 2003.

2. Handschin, Edmund, Petroianu& Alexandar. “Energy Management Systems”, Springer Verlag, 1990

Reference Books

1. Green, J. N, Wilson, R, “Control and Automation of Electric Power Distribution Systems”, Taylor and Francis, 2007.

Economics Planning of Energy Systems

Course code: L.T.P

Rationale:

Course Outcome:

Unit-I

Introduction to Energy Economics and Energy Conservation Programme

Basic concepts, energy data, energy cost, energy balance. Relevance of economic and financial viability evaluation of renewable energy technologies, law and elasticity of demand, theory of firm: Production function, output maximization, cost minimization and profit maximization principles.

Unit-II

Basic concepts of Energy Economics and Energy Conservation Programmes

Unit-III

Theory of market, National income and other macroeconomic parameters. Calculation of unit cost of power generation from different sources with examples, Ground rules for investment in Energy sector, Payback period, NPV, IRR and Benefit-cost analysis with example. Socio-economic evaluation of Energy Conservation Programmes:Net Social Benefit considering Free riding concept and Rebound effects,

Unit-IV

Introduction to Energy Policies

Overview of Energy Policies:National energy policy in the last plan periods, Energy use and Energy supply, Overview of renewable energy policy and the Five Year Plan programmes, Basic concept of Input-Output analysis, Concept of energy multiplier and implication of energy multiplier for analysis of regional and national energy policy.

Unit-V

Model and Analysis of different energy policies and forecasting of Energy Demand

Models and Analysis: Economic approach to environmental protection and management, Interdependence of energy, economy and environment, Modeling concepts and application of SIMA model and I-O model for energy policy analysis.

Forecasting of Energy Demand

Simulation and forecasting of future energy demand consistent with macroeconomic parameters in India. Basic concept of Econometrics and statistical analysis (Multiple Regression), Case studies on financial and economic feasibility evaluation of renewable energy projects.

Text Book

1. EA Diulio, Macroeconomic Theory, Schaum's Outline Series, nd Ed, McGraw-Hill Publishing Company (1990)

2. R Loulou, P R Shukla and A Kanudia, Energy and Environment Policies for a sustainable Future, Allied Publishers Ltd, New Delhi, 1997

Reference Books

1. J Parikh, Energy Models for 2000 and Beyond, Tata McGraw-Hill Publishing Company Ltd, New Delhi,1997

2. Energy Economics -A.V.Desai (Wiley Eastern) Energy Economics - Simple Payback Period, Time Value of Money, IRR, NPV, Life Cycle Costing, Cost of Saved Energy, Cost of Energy generated, Examples from energy generation and conservation.

3. Campbell, H. F., & Brown, R. P. (2003). Benefit-cost analysis: financial and economic appraisal using spreadsheets. Cambridge University Press.

4. Kandpal, T. C., & Garg, H. P. (2003). Financial evaluation of renewable energy technologies. MacMillam India Limited.

Waste Management and Energy Recovery

Course code: L.T.P

Rationale:

Course Outcome:

Unit-I

Introduction

Sources, generation and estimation, types, compositions, Properties - physical, chemical and biological. Collection, Transfer stations, waste minimization, Recycling of municipal wastes, regulations.

Unit-II

Collection, Transportation And Processing Techniques

Unit-III

Onsite handling, storage, processing, types of waste collection mechanisms, Transfer stations - types and location, Manual component separation and other sepaation techniques.

Size Reduction

Unit-IV

Aerobic Composting, Incineration for Medical /Pharmaceutical Waste. Land Fill Method- Types, Methods & siting consideration. Composition, characteristics, generation. Control of land fill leachate & gases, an environmental monitoring system for landfill gases

Unit-V

Hazardous Waste

Definition, potential sources, impact on the environment, transportation regulations, risk assessment, remediation technologies. Private-public partnership, Government initiatives. Disposal of Hazardous Waste - Underground Storage Tanks Construction, Installation and Closure.

Managing wastes

Basics, types, working and typical conversion efficiencies of composting, anaerobic digestion, combustion, incineration, gasification, pyrolysis.

Environmental Impact Assessment

Production and assessment of impacts due to air and water pollution on the environment. Environment Impact Assessment in the land and biological environment. Environmental Effects due to Incineration.

Text Books:

1. Shah, Kanti L., Basics of Solid & Hazardous Waste Management Technology, Prentice Hall 1999.

2. Barthwal, R. R., Environmental Impact Assessment, New Age International Publishers (P) Ltd 2012 3. Parker, Colin, & Roberts, Energy from Waste - An Evaluation of Conversion Technologies, Elsevier Applied Science, London, 1985

Reference Books:

1. Adaptive environmental assessment and Management Ed. C. S. Holling, John Wiley and Sons 2005

2. S.A. Abbasi and N. Abbasi, Renewable Energy Sources and Their Environmental Impact, Prentice Hall of India 2010

3. Environmental Impact Assessment L.W.Canter, McGraw Hill Book Company 1995

4. Barthwal, R. R., Environmental Impact Assessment, New Age International Publishers (P) Ltd 2012

Electrical Safety, Operations, Regulations

Course code: L.T.P

Rationale:

Course Outcome:

Unit-I

Electrical safety: Safety of the self. Safety of the equipments, Safety of the public. PPE. General guidelines on

Unit-II

earthing and protection. Operations: Sign boards, tagging system and procedures. Safe operating procedures, case

Unit-III

studies and, safety audit basics. Regulations: IS, IEEE standards, Indian Electricity rules and regulations.

Unit-IV

HSC- A Practical guide VOL. 1 to 4, National Safety Council, India.

Unit-V

IS 5216 (Part I)- 1982, “Recommendations on safety procedures and practices in electric work”.

SP 30 -1985 Special publication-National Electric Code, “Section-14: Electric Aspects of building services”.

IEEE Standard 902.

Linear and Nonlinear Systems

Course code: L.T.P

Rationale:

Course Outcome:

Unit-I

Characteristics of linear systems, modeling and analysis of linear time-invariant systems using state-space approach,

Unit-II

analysis of linear time-variant systems. Characteristics of nonlinear systems, common types of nonlinearities, phase plane

Unit-III

analysis, describing function analysis.

Thomas Kailath, Linear Systems, Prentice-Hall, 1980.

K. Ogata, State-Space Analysis of Control Systems, Prentice-Hall, 1967. John E. Gibson, Non linear Automatic

Control, McGraw-Hill, 1963.

Electronic Measurements and Instrumentation

Course code: L.T.P

Rationale:

Course Outcome:

Unit-I

Measurement systems, electromechanical instruments, bridges, electronic instrumentation, oscilloscopes, signal

Unit-II

analysis, frequency, time interval measurements, physical parameter measurements, transducers, data acquisition systems.

B. H. Oliver, J. M. Cage, Electronic Measurements and Instrumentation, McGraw-Hill, 1975

Albert D. Helfrick, William D. Cooper, Modern Electronic Instrumentation and Measurement Techniques, PHI.

Electric Power Stations

Course code: L.T.P

Rationale:

Course Outcome:

Unit-I

Choice of site for power plants. Thermal power plant: General layout, air and flue-gas circuit, fuel and ash handling

Unit-II

circuit, cooling water circuit, steam and feed water circuit. Nuclear power plant: General layout, heat exchangers,

Unit-III

moderators, coolants, control rods. Hydro power plant: Site selection, general layout, type of hydropower plants,

hydrographs. Characteristics of hydro turbines. Electrical equipment in generating stations: General layout, excitation

Unit-IV

systems and voltage regulation. Substation layout, components of substation. bus-bar arrangements, current-limiting

Unit-V

reactors and their location. Safety and coordination. Load forecasting and sharing: Load curve and load duration

curves, load factor, diversity factor, plant factor and plant use factor, demand factor, load sharing between base and

peak load stations.

M. V. Deshpande, Electrical Power Stations.

Tata Electric Co. , Operator Training Manual.

Professional Electives-VI

Network Synthesis

Course code: L.T.P

Rationale:

Course Outcome:

Unit-I

Review of mathematics for network synthesis Partial -fraction expansion, Continued – fraction expansion, Bilinear transformation. The positive real concept - Hurwitz polynomials, analytic tests for positive real functions, positive --definite and positive -- semi -- definite quadratic forms. Realizability conditions for networks with and without transformers (magnetic coupling) Realization of driving -- point functions -- Canonical forms – LC, RC, and RL driving -point functions.

Louis Weinberg, Network Analysis and Synthesis, McGraw – Hill, New York, 1962 M. E.

Van Valkenburg, Modern Network Synthesis, Prentice – Hall, New Jersey

Traveling Waves on Transmission Systems

Course code: L.T.P

Rationale:

Course Outcome:

Unit-I

Introduction to the line equations. Attenuation and distortion of traveling waves. Reflection of traveling waves. Successive reflections: The reflection lattice, construction and use of the lattice-diagram, Charging of a line from various sources, Reflection between a capacitor and a resistor, effect of short lengths of cable, effect of insulator capacitance. Traveling waves on multi conductor systems. Theory of ground-wires: Direct stroke to a tower, effect of reflections up and down the tower, tower grounding. The counterpoise: Multi velocity waves on the counterpoise, tests on the counterpoise, successive reflections on the insulated counterpoise. Induced lightning surges: The field gradient, induced surges with ideal ground wires. Arcing grounds: Normal frequency arc extinction – single-phase and three-phase, oscillatory- frequency arc extinction, high-frequency effects, interruption of line-charging currents, cancellation waves, initiated waves, steady-state waves, recovery voltage, restriking phenomena.

Reference:

L. V. Bewley, Traveling Waves on Transmission Systems, John Wiley and Sons, 1951.

H. H. Skilling, Electric Transmission Lines, McGraw-Hill, 1951.

L. F. Woodruff, Principles of Electric Power Transmission, John Wiley and Sons, 1952 .

Statistical Foundation for Electrical Engineers

Course code: L.T.P

Rationale:

Course Outcome:

Unit-I

Probability: Axioms, Sample spaces (continuous & discrete), Density, Distribution and Mass functions and their applications. Random Variable: Single, Multiple, Continuous and Discrete, statistical operations and limit theorems. General Distributions and their practical significance. Functions of random variables: Probability distribution functions of functions of random variables. Random Process: Concept, Classification, Temporal and Spectral characterization, and Statistical Estimation: Estimation of variables, Estimation of parameters. Testing of hypothesis. Analysis of linear systems to Random signals and optimum linear systems, and Optimum Wiener Solutions.

Reference:

Davenport W. B Jr, Probability and Random Process, An Introduction for Applied Scientists and Engineers, McGraw-Hill.

Peyton Z. Peebles JR, Probability, Random Variables & Random Signal Principles, 4thEdition, McGraw-Hill.

Leon-Garcia, Probability and Random Process for Electrical Engineering, Addition-Wesley.

Viniotis Y, Probability and Random Process for Electrical Engineers, McGraw-Hill.

Papoulis A, Probability, Random Variables and Stochastic Processes, McGraw-Hill.

Mayer P. L. , Introductory Probability and Statistical applications, Second Edition, Oxford and IBH publishing Co. Pvt. Ltd. , New Delhi.

Energy Auditing

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

Introduction to energy audit. Purpose, methodology, case studies of few selected industries, analysis of results and inference, standards, instruments used in energy auditing.

Reference:

Shirley J. Hansen, James W. Brown, Jim Hansen, Investment Grade Energy Audit, Marcel Dekker, 2003.

Microprocessors and Microcontrollers

Course code: L.T.P

Rationale:

Course Outcome:

Unit-I

Basics of finite state machines, Von Neumann Architecture, functional blocks of a microcomputer, architecture of 8-bit/16-bit Microprocessors/Microcontrollers [viz. Intel 8051 family, MOTOROLA 68HXX, ARM Core etc.]. Programmers' model of any one microprocessor/microcontroller chosen for detailed study, instruction set, chip configuration and programming, use of development and debug tools, interface applications. Laboratory exercises.

Reference:

Intel Corporation, 8-bit Microcontroller Handbook, Intel Corporation, 1990.

ARM® Core Processor Hand book.

John B. Peatman, Design with Microcontrollers, McGraw-Hill, 1995.

Andrew N. Sloss, Dominic Symes, Chris Wright, John Rayfield, ARM System Developer's Guide, Designing and

Optimizing System Software, Elsevier, 2004.

Operation and control of Power Systems

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

Economic operation of power systems: Economic load dispatch, unit commitment. Load frequency control: Modeling of components of generating systems, concept of coherent units, operation of single area. Introduction to multi-area systems. Sources of reactive power. Introduction to contingency analysis. State estimation: Importance of state estimation, DC state estimation. Energy interchange evaluation.

Reference:

O. I. Elgerd, Electric Energy Systems Theory: An Introduction, McGraw-Hill, 1971.

I. J. Nagrath, D. P. Kothari, Modern Power System Analysis, TMH.

S. S. Rao, Optimisation Theory and Applications.

Allen J. Wood, Bruce F. Wollenberg, Power Generation Operation and Control, 2nd Edition, John Wiley and Sons,1996.

Special Machines and Drives

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

Method of control and application of brushless DC motor, PMSM, stepper motor, AC servomotor, universal motor. Electric drive, motor rating, heating effects, electric braking, modification of speed- torque characteristic of an induction motor by V/f control, starting and braking. Synchronous motor --Speed torque and torque angle characteristics by V/f control, braking.

Reference:

G. K. Dubey, Fundamentals of Electrical Drives, Narosa.

A . E. Fitzerald, C. Kingsley, S. D Umans, Electric Machinery, McGraw-Hill.

S. K. Pillai, A First Course on Electric Drives, Wiley Eastern, 1990.

Power Electronics Applications to Power Systems

Course code: **L.T.P**

Rationale:

Course Outcome:

HVDC systems: Classical HVDC systems, CCC systems, HVDC Light systems. Application of FACTS devices such as SVC, TCSC, SSS, UPFC to improve steady state and dynamic behaviour of power systems. Modeling of HVDC systems and FACTS devices to perform system studies.

Reference:

N. G. Hingorani, L. Gyugi, Understanding FACTS, IEEE Press, 2001.

P. Kundur, Power System Stability and Control, McGraw-Hill, 1994.

Electric Energy Systems

Course code: L.T.P

Rationale:

Course Outcome:

Unit-I

Conventional and non- conventional energy sources and systems: Generation, transmission and distribution schemes, energy conservation systems, energy efficient equipment and controllers. Energy audit.

Reference:

Olle I. Elgerd, Electric Energy System Theory: An Introduction, TMH, 1982.

I. J. Nagrath, D. P. Kothari, Power System Engineering, TMH.

Advanced Control Systems

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

Introduction, review of state space approach to modeling of dynamic system. Introduction to discrete time control system, Signal processing in digital control, models of digital control devices and systems, z -plane analysis of discrete time control system, transient response analysis, design specifications and performance indices, design of digital control algorithms, state variable analysis of digital control systems, Pole placement design and state observers, linear quadratic optimal control

K. Ogata, Discrete Time Control Systems, 2nd Edition, Pearson

Education. M. Gopal, Digital Control and State Variable Methods, TMH

Professional Electives-VII

Power System Protection

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

Introduction to power system protection, Review of conventional power system protection schemes, power apparatus protection: viz. transformer, motor, generator, bus bar, transmission and distribution line protection schemes, Introduction to computer aided protection, numeric relay hardware design, digital protection algorithms, recent trends in power apparatus protection methodology, concepts of adaptive relaying and application of soft computing methods in numeric relaying.

Warrington, Protective Relays – Their theory and practice, Volumes. I, II, and III, Chapman and Hall.

Arun G. Phadke, J. S. Thorpe, Computer Relaying for Power Systems, Research Studies Press.

Gerhard Ziegler, Numerical Distance Protection: Principles and Applications.

A. T. Johns, S. K. Salman, Digital Protection for Power Systems, IEE, 1995.

M. S. Sachdev (Coordinator), IEEE Tutorial Course on Advancement in Microprocessor-based Protection and Communication, IEEE, 1979.

HVDC Transmission

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

Need, Basic principle of conversion, economics of different configurations, The Graetz bridge circuit, analysis, overlap, firing delay, inversion, converter control, tap-changing control, power reversal, measuring devices, filters, circuit breaker, lighting arrester, DCCT, MRT. MTDC systems, interaction between AC and DC Systems, voltage stability, power modulation, Introduction to Voltage Source Converter based HVDC System, future of the HVDC transmission systems, research and development

E. W. Kimbark, Direct Current Transmission.

K. R. Padiyar, Power Transmission by Direct Current, Wiley Eastern, 1990.

Recent Publications of relevance.

Electromagnetic Compatibility

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

Review of EM theory. EMI from apparatus and circuits. EMI measurements. Shielding and grounding. EMI filters. Electrostatic discharge. EMC standards.

H. W. Ott, Noise Reduction Techniques in Electronic Systems.

V. Prasad Kodali, Engineering Electromagnetic Compatibility, S. Chand & Co.

Operation of Power Systems Under Deregulation

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

Fundamentals of deregulation, restructuring models and trading arrangements, different models of deregulation, operation and control, wheeling charges and pricing, Role of FACTS controllers and distributed generation in restructured environment, developments in India, IT applications in restructured markets.

K. Bhattacharya, M. H J Bollen and J. E Daalder, “Operation of Restructured Power Systems”, Kluwer Academic Publisher, USA, 2001.

L. Philipson and H. L. Willis, “Understanding Electric Utilities and Deregulation”, Marcel Dekkar Inc. 1999.

M. Shahidehpour and M. Alomoush, “Restructured Electrical Power Systems, Operation, Trading and Volatility”, Marcel Dekkar Inc. 2001.

Steven Stoft, “Power System Economics: Designing Markets for Eligibility”. John Wiley & Sons, 2002

Advanced Power Electronics

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

Power devices, design of inductors, transformers, selection of core, design of capacitors, selection of capacitors for different applications. AC to DC converters, multilevel inverters, DC to DC converters, hard switch converters, design and analysis, isolated converters, resonant converters.

Ned Mohan, Undeland, Robbins, Power Electronics.

M. H. Rashid, Power Electronic Circuits – Devices and Applications.

Flexible AC Transmission Systems

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

Transmission system performance, compensation approaches, static var systems, VSI based FACTS controllers –STATCOM, UPFC, TCSC, TCPAR, TCBR. Applications: Transient stability improvement. Introduction to custom power.

K. R. Padiyar, Power System Dynamics, Stability and Control, 2nd Edition, B. S. Publishers.

Prabha Kundur, Power System Stability and Control, McGraw-Hill EPRI Power System Engineering Series, 1994.

Narain G. Hingorani, Laszlo Gyugyi, Understanding FACTS – Concepts and Technology of Flexible AC

Transmission Systems, IEEE Press, 2001.

High Voltage Engineering

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

Electric breakdown in solid, liquid and gas dielectrics. Generation of high AC, DC and impulse voltages. Impulse current generators. Methods of measuring high AC, DC and impulse voltages and current. Partial discharge.

E. Kuffel, Zengal, High Voltage Engineering.

D. Kind, An Introduction to High Voltage Experimental

Techniques. Kamaraju, Naidu, High Voltage Engineering.

C. L. Wadhwa, High Voltage Engineering.

Computer Network

Course code: L.T.P

Rationale:

Course Outcome:

Unit-I

Introduction - Architecture, Network hardware and software. Physical layer- Guided transmission media -Cable television.

Unit-II

Data Link Layer –Design issues–Channel allocation problem –Multiple access protocols - Ethernet – Wireless LAN -802.11architecture.

Unit-III

Network Layer - Design issues – Routing algorithms - Congestion control algorithms - Quality of Service – Internet working.

Unit-IV

Transport Layer - Transport service -Elements of transport protocols-User Datagram Protocol-Transmission Control Protocol.

Unit-V

Application Layer – DNS – Electronic mail – World Wide Web – Multimedia – Network security.

References

1. Behrouz A. Forouzan," Data Communications and Networking", McGraw Hill, Sixth edition, 2022

2. W.Stallings, ‘Data and Computer Communications’, Pearson Education, 8th Edition, 2007.

3. James F.Kurose, Keith W.Ross, " Computer Networking A Top-Down Approach", Pearson Education, Eigth edition, 2022, Pearson India.

4. Andrew S. Tanenbaum, Nick Feamster, David J.Wetherall," Computer Networks", Pearson Education, Sixth edition, 2022, Pearson India

5. Douglas E.Comer, 'Computer Networks and Internets’, Pearson education, 4th Edition, 2008.

6. Larry L. Peterson and Bruce S. Davie, ‘Computer Networks - A Systems Approach’, Harcourt Asia/Morgan Kaufmann, 5th Edition, 2011.

Computer Organization and Architecture

Course code: L.T.P

Rationale:

Course Outcome:

Unit-I

Computer – Functional units, Addressing modes, Instruction formats, Stacks and Subroutines. Processing Unit – Execution of instructions - Control step sequence.

Unit-II

Control Design - Hardwired control- design - multiplier control unit - CPU control unit and Micro programmed control – microinstructions - Sequencing - perfecting.

Unit-III

Arithmetic and Logic Unit-Fixed point and floating-point numbers and operations. Design of arithmetic units.

Unit-IV

Memories - cache memories - virtual memories. Input-Output Organization - Data transfer-synchronization- Interrupt handling-I/O interfaces

Unit-V

Introduction to parallel processing- Generation of computer systems – Parallelism in uniprocessor system – Parallel computer structures- architectural classification schemes.

References

1. David A. Patterson and John L. Hennessy, ‘Computer Organization and Design: The Hardware/Software Interface’, 4th Edition, Elsevier, 2009.

2. Morris Mano.M., ‘Computer System Architecture’, Prentice Hall India, 3rd Edition 2008.

3. William Stallings, ‘Computer Organization and Architecture – Designing for Performance’, 8th Edition, Pearson Education, 2010.

4. Behrooz Parhami, ‘Computer Architecture from up to Super Computer’, Oxford press, Reprinted 2014.

5. John P. Hayes, ‘Computer Architecture and Organization’, Tata McGraw-Hill, 3rd Edition, 1998.

6. Carl Hamachar, Zvonkoran Vranesic, Safwatzaky, ‘Computer Organization’, Tata McGraw-Hill, 6th Revised Edition, 2011.

Operation Research

Course code: L.T.P

Rationale:

Course Outcome:

Unit-I

Linear Programming: Basic concepts – Mathematical formulation of L.P.P – Graphical solution – simplex method – Charnes' Big-M method – Two-phase method – Dual Theory - Dual simplex method.

Unit-II

Sensitivity Analysis - Transportation and Assignment problems: Transportation problem – Assignment problem.

Unit-III

Integer programming and CPM-PERT: Gomory's method – Branch and bound technique – Critical path in networks – CPM – Time and Cost aspects in networks – PERT.

Unit-IV

Queueing Theory and Inventory models: Classification of queues – Poisson arrivals – Exponential service time – M/M/1 and M/M/c models – Inventory control – E.O.Q. with uniform demand, with finite rate of replenishment and with shortage – Buffer stock – Inventory with price breaks – Basic probabilistic models.

Unit-V

Dynamic programming: Recursive equation approach – applications to shortest path network, Inventory and production control – solution of LPP by dynamic programming - Travelling salesman problem.

References

1. Hamdy A. Taha, 'Operation Research – An Introduction', Pearson Education, 9th Edition, 2014.

2. Gass, S.I., 'Linear Programming: Methods and Applications', McGraw-Hill Ltd, 1975.

3. Hillier, F.S., and Lieberman, G.J., 'Operation Research', McGraw-Hill Ltd, 9th Edition, 2009.

4. Harvey. M.Wagner, 'Principles of Operations Research with Applications to Managerial Decisions', Prentice Hall India, 2nd Edition, 1999.

5. Gillet, M.N., 'Introduction to Operation Research', Tata McGraw-Hill Education Pvt Ltd, 1st Edition, 2010

Open Electives-II

Wearable Technology

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

Introduction to Wearable Technology 9 Hour

Fundamentals of wearable technology- History of wearable technology-Need for wearable systems- emergence of wearable computing and wearable electronics, Industry sectors overview, E-Textiles.

Unit-II

- Wearable Sensors and Applications 9 Hour

Sensors for wearable system-Types -Temperature sensitive fabrics-electrochemical sensors-Resistive sensors-Wearable applications

Unit-III

- Energy Harvesting for Wearable Devices 9 Hour

Solar cell, heat source for power generation, Hybrid thermoelectric photovoltaic energy harvests, Wearable Optical Sensors, UV exposure indicators, speech recognition using lasers

Unit-IV

Wearable Devices 9 Hour

Role of Wearables, Attributes of Wearables, The Meta Wearables, and Social Aspects: Interpretation of Aesthetics, Adoption of Innovation, On-Body Interaction; Case Study, Intelligent clothing, Wearables:

Challenges and Opportunities, Future and Research Roadmap.

Unit-V

- Role of IoT in Wearable Devices 9 Hour

Smart connectivity and Big picture of IoT-smart devices, networks, Wireless technologies and need for data analysis. Evolution of wearable technology, Wearable IoT based case studies.

Learning Resources

1. Michael J. McGrath, Cliodhna Ni Scanaill, Dawn Nafus, “Sensor Technologies: Healthcare, Wellness and Environmental Applications”, A press Media LLC, first edition, 2015.

2. Subhas C. Mukhopadhyay, “Wearable Electronics Sensors-For Safe and Healthy Living”, Springer International Publishing, first edition, 2015.

3. Edward Sazonov, Michael R Neuman, “Wearable Sensors: Fundamentals, Implementation and Applications”, Academic Press, Elsevier, second edition, 2018.

E-waste Management

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

Introduction to E-Waste Management **9 Hour**

Introduction, Indian and global scenario of e-Waste, Possible hazardous substances present in e-waste, Steps in recycling and recovery of materials

Unit-II

E-Waste Hazardous on Global Trade 9 Hour

Essential factors in global waste trade economy, Import of hazardous e-waste in India, E-waste economy in the organized and unorganized sector. Estimation and recycling of e-waste in metro cities of India.

Unit-III

E-Waste Control Measures 9 Hour

Need for stringent health safeguards and environmental protection laws in India, Extended Producers Responsibility, Administrative Controls & Engineering controls, Reduction of waste at source

Unit-IV

E-Waste Legislation 9 Hour

E-waste (Management and Handling) Rules, Government assistance for TSDFs. The international legislation – conventions, Restrictions of Hazardous Substances Directive.

Unit-V

- Environmental E-Waste Management 9 Hour

Emerging recycling and recovery technologies, Guidelines for environmentally sound management of e-waste, Life cycle assessment of a product, Case studies and unique initiatives from around the world.

Learning

Resources

1. Johri R., “E-waste: implications, regulations, and management in India and current global best practices”, TERI Press, second edition, 2015.

2. Hester R.E., Harrison R.M, “Electronic Waste Management Science”, second edition, 2012.

3. Fowler B, “Electronic Waste – Toxicology and Public Health Issues”, Elsevier, first edition, 2017.

4. Waste to resources - A waste management Handbook, The Energy and Resources Institute (TERI), 2014.

Energy Efficient Practices

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

Energy Scenario 9 Hour

Introduction: Commercial and Non-commercial energy, primary and secondary energy resources, energy needs of growing economy, energy pricing, Energy Conservation Act-2001, Bureau of Energy Efficiency.

Unit-II

- Electrical Supply System 9 Hour

Electrical supply system, components of AC power, Concept of sanctioned load, maximum demand, contract demand, and AC machines.

Unit-III

- Energy Efficient Practices 9 Hour

Energy efficiency in electrical utilities, tips for energy saving, compressed air system, Energy saving opportunities in HVAC and refrigeration system, impact of Power Electronics in energy efficiency

Unit-IV

- Lighting and Distributed Generation Systems 9 Hour

Introduction, Basic definitions, Types of different lamps, design and their features, energy efficiency opportunities in lighting and distributed generation systems

Unit-V

- Industrial Sector 9 Hour

Energy efficiency in industrial sector, main challenges to improve energy efficiency in industry, Energy Efficient Technologies, Industrial Automation, Industrial Sensors

Learning Resources

1. Bose, B. K., “Global energy scenario and impact of power electronics in 21st century”, IEEE Transactions on Industrial Electronics, 60(7), 2638-2651, 2012.

2. Hegger, M., Fuchs, M., Stark, T., & Zeumer, M., “Energy manual: sustainable architecture”, Walter de Gruyter, 2012.

3. El-Hawary, M. E., “Electrical energy systems”, CRC Press, second edition, 2018.

4. Malinauskaite, J., Jouhara, H., Ahmad, L., Milani, M., Montorsi, L., & Venturelli, M., “Energy efficiency in industry: EU and national policies in Italy and the UK. Energy”, 172, 255-269, 2019.

5.Dobrotkova, Z., Lukas, A., Singh, J., “Energy Efficiency in Industry", World Bank Group, 2018.

Surveillance Technology

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

– Surveillance - History and Development 9 Hour

Surveillance- Its emergence- Abuse and use- Public dispute and accountability-Evolution-Discoveries and Inventions- Devices, components- Computers and World wide web- Long distance communication-Data

security- Key developments- Nature of Surveillance.

Unit-II

- Surveillance by Optics 9 Hour

Visual surveillance-Security with camera vision-New developments- Fish eye lens, scanners, micro cameras-Selective vision-Robotic sensors-CCTV-Aerial surveillance-Balloons-Uninhabited aerial vehicles-Aircrafts

(border, military, urban) surveillance – Quadro-copter-Drones - Satellite surveillance - Early warning - GPS –Traffic surveillance- License plate recognition.

Unit-III

- Radio and Internet Surveillance 9 Hour

Audio surveillance-Applications-Telecom Surveillance-Eavesdropping-Wiretapping-Privacy acts-Multi-functionality Phones as spy- Radio surveillance-RFID chips-Product protection, control and tracking-Internet

surveillance-Wired, wireless communications-Spyware-QR codes-Search engine surveillance-Social media monitoring-Web browser surveillance

Unit-IV

- Human, Animal, Sensor Surveillance 9 Hour

Employer surveillance-Data cards-Biometrics-Finger-Iris and retina scanners-Facial recognition-Voice-Speech-Sensor based surveillance-Alcohol sensor-Seismic Surveillance-Animal surveillance-Genetics-DNA

sampling, profiling-CODIS-NDIS.

Unit-V

- Indian Acts, Laws, Agencies, Amendments 9 Hour

Justice AP Shah Privacy Principles-International principles on the application of human rights to communications surveillance-Amendments to National laws on surveillance-Amendments to license agreements- Periodic review of legislation and practices-Penalties-Safeguards for International co-operation-Authorizing authorities-Content requirements for surveillance directions.

Learning Resources

1. J. K Petersen, “Introduction to Surveillance Studies”, CRC Press, first edition, 2013.

2. Policy-recommendations-for-surveillance-law-in-india-and-analysis-of-legal-provisions-onsurveillance-in-india-and-the-necessary-and-proportionate-principles.pdf (cis-india.org).
3. Vlado Damjanovski, “CCTV-From Light to Pixels”, Butterworth-Heinemann, Elsevier, third edition, 2014.

Sustainable Development Practices

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

- Introduction to Sustainable Development 9 Hour

Definition, scope and elements, Stake holders of sustainable development: People, Government, Investors, Industry, Judiciary, and international organizations working for sustainable development.

Unit-II

- Developmental Needs of Indian Society 9 Hour

Poverty, unemployment, inadequate housing, unsafe drinking water, deficiency of energy sources and supply, sanitation, unscientific waste management, lack of transportation facilities, unskilled work force and

apathy towards political activities.

Unit-III

- Social Interventions for Sustainable Development 9 Hour

Education, skill development, people's participation in decision making, women empowerment, inclusive society, human rights, tolerance to diversity, reduction of health inequality, social safety net and Population

control

Unit-IV

- Environment Protection Measures 9 Hour

Environment protection policies, waste management, pollution control, reduce the use, reuse and recycle, sustainable energy, preservation of forest and water sources.

Unit-V

- Integrated Approaches 9 Hour

Innovative models of sustainable development. Public private partnership, decentralization of power. Strategies to become a developed country, Future trends in integrated approaches, case study

Learning

Resources

1. Ghate, P., “Indian microfinance: The challenges of rapid growth”, SAGE Publications,

first edition, 2007.

2. Green, F.J., Chambers, B.W., “The Politics of Participation in Sustainable Development

Governance”, United Nations University Press, first edition, 2006.

3. Chopra, K., Gopal, K., “Operationalising Sustainable Development”, Sage Publications, first edition,

1999.

4. Hans, C.B., Christina, V., “Sustainable Development in International and National Law”, Groningen:

Maunsbach Europa Law Publishing, first edition, 2008.

Clean and Green Energy

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

- Fundamentals of Energy Systems and Solar Radiation 9 Hour

Introduction to Energy, classification of Energy Resources, Energy for Sustainable Development, Analysis of Solar Radiation Data

Unit-II

- Solar Thermal Conversion and Solar PV Systems 9 Hour

Solar Collectors, Comparison of Collectors, Selection of Collector for Various Applications, History of PV, Equivalent Circuit and Electrical Characteristics of Silicon PV Cells, Solar Panel Applications.

Unit-III

- Wind, Tidal and Wave Energy 9 Hour

Nature of the Wind, Power in the Wind, Forces on the Blades and Wind Energy Conversion, Types of Wind Machines, Applications of Wind Energy, Tidal Power, Components and Operation of Tidal Power Plant,

Wave Energy, Wave Energy Conversion Devices

Unit-IV

- Bio – Energy 9 Hour

Photo Synthesis, Usable Forms of Biomass, Biomass Resources, Biomass conversion technologies, Types of Biogas Plants, Applications

Unit-V

- Geothermal and Oceanic Energy 9 Hour

Energy inside the Earth, Geothermal Wells, Types of Geothermal Power Plants, Ocean Energy Resources, Types of OTEC, Methods of Ocean Thermal Electric Power Generation.

Learning Resources

1. G.D.Rai, “Non-Conventional Energy Sources”, Khanna Publishers, sixth edition, 2009.

2. R.K. Rajput, “Non-Conventional Energy Sources and Utilization”, S.Chand and

Company Ltd. second edition, 2014. 3. John Twidell and Tony Weir, “Renewable Energy resources”, Routledge, third edition, 2015. 4. B.H.Khan, “Non-Conventional Energy Resources”, Tata McGrawHill, third edition, 2017.

Smart Cities and Communities

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

- Fundamentals of Smart City Infrastructure 9 Hour

Introduction - History of Smart City world and India – Necessity of Smart City - Smart Governance - Challenges of managing infrastructure in world and India.

Unit-II

- Planning and Development of Smart City Infrastructure 9 Hour

City Wide Network - Wireless Networks - sustainable green building – safety - Policy instruments for inclusive smart city development - Smart infrastructure design principles

Unit-III

- Intelligent Transport Systems 9 Hour

Introduction to Intelligent Transportation Systems (ITS) - Environmental Aspects of ITS - Conceptualization of smart urban transportation systems - Smart vehicles and fuels GIS, GPS - E-ticketing.

Unit-IV

- Management of Water Resources and Related Infrastructure 9 Hour

Storage and conveyance system of water- sustainable water and sanitation - sewerage system - flood management - conservation system.

Unit-V

- Infrastructure Management System Policy for Smart City 9 Hour

Integrated infrastructure management systems for smart city - applications for existing smart city - Worldwide policies for smart city - Government of India – policy for smart city, Mission statement and guidelines - Case studies of smart city.

Learning Resources

1. Xianyi Li, “Smart City on Future Life - Scientific Planning and Construction”, Chinese Edition, 2012.

2. Nicos Komninos, “The Age of Intelligent Cities: Smart Environments and Innovation-forall Strategies (Regions and Cities)”, first edition, 2018.

3. Anthony Townsend, “Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia”, W. W. Norton & Company; reprint edition, 2014.

4. Smart cities – Ranking of European medium-sized cities". Smart Cities. Vienna: Centre of Regional Science, Giffinger, Rudolf; Christian Fertner; Hans Kramar; Robert Kalasek; Nataša Pichler- Milanovic; Evert Meijers, 2007. www.smart-cities.eu

5. Mission statement and guidelines on Smart City Scheme, Government of India, Ministry of Urban Development, http://smartcities.gov.in/upload/uploadfiles/files/Smart City Guidelin**es.**

Electrical Trading

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

- Introduction to Electrical Market 9 Hour

Introduction- Deregulation, Types of Restructuring Model, Major Players, Natural Gas, Electricity, Electrical Generation, Bilateral Contracts Model, Need of ISO, Role of ISO, Hybrid Model, Elastic – Inelastic MarketsCost components in transmission- Mechanics of the Physical Electricity Market, Crude Oil Markets- Issues in energy trading.

Unit-II

- Power Transaction on Trading 9 Hour

Formation of power pools- Economic Exchange of Energy - Energy Brokerage system. Types of electricity market- Structure of UK Electricity deregulated market - Structure of Nordic Electricity deregulated Market- Power wheeling - Types of wheeling transactions.

Unit-III

- Energy Trading 9 Hour

Electric Energy Trading – Introduction-Essence of Electric Energy Trading-Energy Trading Framework -Derivative Instruments of Energy Trading-Forward Contracts-Future Contracts-Option Contracts- Put Options

(Puts) contracts- Energy trading HUBS--Brokers in Electricity Trading- Green Power Trading

Unit-IV

- Electricity Pricing 9 Hour

Introduction - Volatility, Risk and-Forecasting-Factors in Volatility-Measuring Volatility-Tutorial Problems of Measuring Volatility-Electricity Pricing Risk-Electricity Price Indexes – case study on volatility -Challenges

of Electricity Pricing-Reliable Forward Curves-Construction of Forward Price Curves-Price Forecasting, Short term Price Forecasting.

Unit-V

- Information Communication on Trading 9 Hour

Open Access Same Time Information System (OASIS) – Introduction-FERC 889-Structure of OASIS – Historical Background-Functionality of OASIS-Architecture of OASIS-OASIS Phases Phase – 1, Phase -1A,

Phase -2-Types of information available in OASIS-Information Requirements of OASIS-Users of OASIS-Transfer capability of OASIS –Definitions PJM OASIS, ERCOT OASIS.

Learning Resources

1. Mohammad Shahidehpoura, Muwaffaq A lomoush, "Restructured Electric Power

System operation trading and volatility", Macsel Dekker Inc, first edition, 2001.

2. Kankar Bhattacharya, "Operation of Restructured Power Systems", Kluwer academic

publishers, first edition, 2001.

3. Zaccour.G. "Deregulation of Electric Utilities", Kluwer academic publishers, first edition, 1998.

4. Lai L L, "Power System Restructuring and Deregulation: Trading, Performance and Information

Technology", John Wiley, first edition, 2001.

1. THE ELECTRICITY ACT, 2003, http://www.cercind.gov.in/Act-with-amendment.pdf

Unmanned Aerial Vehicle

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

- Introduction to Unmanned Aerial Vehicles 9 Hour

History of UAVs; Types of UAVs: Based on weight- Nano, Micro, Small, Medium, and Large; Based on structure: Fixed wing, Rotary Wing, Flapping wing, Fixed wing Hybrid VTOL, Airships; Applications of UAVs;

Commercial vs. Military UAVs; UAV Market; Safety Guidelines.

Unit-II

- Architecture of UAV 9 Hour

Parts: Carbon Frame; BLDC Motor: Construction and Working; Flight Controller: Case study PIXHAWK 4; Electronic Speed Controllers; Antenna and Types; Radio controllers; Telemetry; Propeller and its types:

Materials, No. of blades; Blackbox; FPV camera; Battery; Gimbal; FPV Goggles. Design: Design Requirements; Trade-off; Design Steps; Flight Time Analysis.

Unit-III

- Mathematical Modeling of Quadcopter 9 Hour

Quadcopter Dynamic Model and Simplified Dynamic Model; Control System: Root Locus Design Technique and Frequency Domain Design Technique; Controller Configuration and Architecture: State feedback

control configuration, Series feedback compensation and Time scaled flight control system architecture; PID Controller: MATLAB example

Unit-IV

- Battery Selection and Management Systems 9 Hour

Selection of battery for UAVs; Requirement of Battery Monitoring; Battery State of Charge Estimation methods; Battery Cell equalization problem; Thermal control; Protection interface; SoC Estimation; Energy &

Power estimation; Battery Management System: Definition, Parts: Power Module; Battery; DC/DC Converter; Battery Pack Safety; Battery Standards & Tests

Unit-V

- Sensors and Applications 9 Hour

Accelerometer Sensor, Gyroscope Sensor, Airspeed sensor, Altitude sensor: Radar and Mechanical Altimeter, Pressure sensor, Clock/Timer, Compass, Magnetometer, MEMS inertial Module, Open-Source

Microcontrollers with Case Studies.

Learning Resources

1. Ministry of Civil Aviation, “The Drone Rules”, Gazette of India, 2021,

https://digitalsky.dgca.gov.in/assets/files/Draft-DronesRules2021_Gazette%20version_14-Jul-2021.pdf

2. Jiuchun Jiang, Caiping Zhang, San Ping Jiang, “Fundamentals and Application of

Lithium-ion Battery Management in Electric Drive Vehicles”, Wiley, first edition, 2015.

3. Mohammad H. Sadraey, “Design of Unmanned Aerial Systems”, Wiley, 2020.

4. Paul Gerin Fahlstrom, Thomas James Gleason, “Introduction to UAV Systems”, Wiley

Publication, John Wiley and Sons, Ltd, fourth edition, 2012.

2. Landen Rosen, “Unmanned Aerial Vehicle”, Alpha Publication, 2015.

E-Mobility

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

- Classification of EVs 9 Hour

Overview of EVs and challenges, EV market and Promotion, Parameters comparison, Classification and Configurations of EVs

Unit-II

- E-Mobility 9 Hour

Introduction - concept of E-Mobility, E-Mobility Business Models, E-Mobility for various transportation, E-Mobility for 2 and 3 wheelers

Unit-III

- Energy Storage 9 Hour

Energy Storage Requirements in Hybrid and Electric Vehicles, Various Storage devices, EV energy source technologies, Battery Management System

Unit-IV

- Power Electronics for E-Mobility 9 Hour

Basic Power Electronic Devices, DC–DC Converters for Hybrid Vehicle Systems, Rectifiers and Inverters for E-Mobility

Unit-V

- Charging Station and Testing 9 Hour

Solar Powered Electric Vehicle Charging Station, Requirement to prevent fire for EVs Charging Stations, Testing of EVs charging stations

Learning Resources

1. Iqbal Husain, “Electric and Hybrid vehicles Design Fundamentals”, CRC Press, second edition, 2013.

2. James Larminie, John Lowry, “Electric vehicle technology Explained”, Wiley, second edition, 2012.

3. Ali Emadi, “Hand book of Automotive Power Electronics and Motor Drives”, CRC Press, second edition, 2015.

4. Ali Emadi, Mehrdad Ehsani, John M. Muller, “Vehicular Electric Power Systems”, Marcel Dekker, Inc., 2014

Open Electives-III

Hybrid Electric Vehicle

Course code: L.T.P

Rationale:

Course Outcome:

COURSE CONTENT

Unit-I

Introduction

History of hybrid and Electric vehicles, social and environmental importance of hybrid and electric vehicles.

Unit-II

Electric Drive-trains: Basic concept of electric traction, introduction to various electric drive-train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis.

Unit-III

Hybrid Electric Drive-trains: Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control

Unit-IV

in hybrid drive-train topologies, fuel efficiency analysis.

Unit-V

Electric Propulsion unit

Introduction to electric components used in hybrid and electric vehicles, configuration and control of DC Motor drives, Induction Motor drives, Permanent Magnet Motor drives, and Switch Reluctance Motor drives, drive system efficiency.

Storage and its analysis

Fuel Cell based energy storage and its analysis, Hybridization of different energy storage devices. Sizing the drive system: Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, sizing the power electronics, selecting the energy storage technology, Communications, supporting subsystems.

Energy Management Strategies

Introduction to energy management strategies used in hybrid and electric vehicles, classification of different energy management strategies, Comparison of different energy management strategies. Concept of tariff management in charging stations.

Case Studies: Design of a Hybrid Electric Vehicle (HEV), Design of a Battery Electric Vehicle (BEV).

Text Book

1. Electric and Hybrid Vehicles: Design Fundamentals, by Iqbal Husain, CBC Press, Second Edition, 2010.

2. Vehicular Electric Power Systems by Ali Emadi, Willis Press, 2003

Reference Books

1. Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.

2. Electric Vehicle Technology by James and John, John Wiley & Sons, Ltd First Edition, 2004.

Wireless Network Systems

Course code: **L.T.P**

Rationale:

Course Outcome:

COURSE CONTENT

Unit-I

Introduction

Overview of wireless communications and systems Review of digital communications, Cellular systems from 1G to 3G Wireless 4G systems.

Unit-II

Radio propagation and propagation path-loss model

Free-space attenuation, Multipath channel characteristics, Signal fading statistics, Path-loss models

Unit-III

Fundamentals of cellular communications

Hexagonal cell geometry, Co-channel interference, Cellular system design, Sectoring using directional antennas

Unit-IV

Multiple access techniques

Frequency division multiple access (FDMA), Time division multiple access (TDMA), Code division multiple access (CDMA), Space division multiple access (SDMA), Orthogonal frequency division multiplexing (OFDM), Multicarrier CDMA (MC-CDMA), Random access methods

Unit-V

Wireless Network

Wide-area wireless networks (WANs) GSM – IS-136, IS-95, UMTS, Cdma2000

Long Term Evolution Technologies (LTE)

OFDM, MIMO channels, Space Time Codes, LTE Advanced, Other Wireless systems IEEE 802.11 WLAN (WiFi), WiMAX

Text Books

1. Wireless Communications: Principles and Practice, 2nd Edition. Theodore S. Rappaport, Pearson publications

2. Mobile Wireless Communications. Mischa Schwartz. Paperback (2013) ISBN:9781107412712.Cambridge University Press.

Reference Books:

1. The evolution to 4G cellular systems: LTE-Advanced. Ian F. Akyildiz, David M. GutierrezEstevez, Elias Chavarria Reyes. Broadband Wireless Networking Laboratory, School of Electricaland Computer Engineering, Georgia Institute of Technology.

2. Vijay K. Garg, Wireless Communications and Networking, Morgan Kaufmann Publishers, 2007,ISBN 978-0-12-373580-5

Smart Bio-Medical Instrumentation

Course code: **L.T.P**

Rationale:

Course Outcome:

COURSE CONTENT

Unit-I

Introduction of Bio-medical Instrumentation

Sources of Bioelectric Potentials and Electrodes. Introduction to man-instrument system, components of the man-instrument system, Physiological system of the body, Problems encountered in measuring a living system. Resting and action potentials

Unit-II.

Cardiovascular System and Measurements

The heart and cardiovascular system, ECG, blood pressure and its measurement, respiration and pulse rate, characteristics and measurement of blood flow meter. Measurement of Heart Rate using Stethoscope, Blood pressure using Sphygmomanometer, Pulse Rate and SpO2measurement using Pulse Oximeter

Unit-III

Respiratory systemand Measurements

The physiology of the respiratory system, test and instrument for the mechanics of breathing. Use of Spiro meter.

Unit-IV

Neuro-muscular System and Measurements

Somatic nervous system, EEG, EMG, GSR

Unit-V

Measurement and Recording of Noninvasive Diagnostic Instrument

Principle of ultrasonic measurement, thermography, elements of intensive care monitoring-ray, CT –Scan, MRI, Tonometer, Dialysis and Diathermy .

Biomedical Sensors

Recognize the role of sensors in biomedical instrumentation, basic mechanisms and principles of biomedical sensors.

Text Books

1. Cromwell, L. and Weibell, F.J. and Pfeiffer, E.A., Biomedical Instrumentation and Measurement, Dorling Kingsley (2006) 2ndedition.

2. Carr, J.J. and Brown, J.M., Introduction to Biomedical Equipment Technology, Prentice Hall India (PHI) (2000) 4thedition.

Reference Books

1. Geddes, L.A., and Baker, L.E., Principles of Applied Biomedical Instrumentation, Wiley InternationalScience (1989) 3rd edition.

2. Khandpur, R.S., Handbook of Biomedical Instrumentation, McGraw Hill (2003) 2ndedition.

3. Webster, J.G., Medical Instrumentation Application and Design, John Wiley (2007) 3rdedition

4. Medical Device Technologies: A Systems Based Overview Using Engineering Standards, G. Baura, Academic Press, 2011

IoT in Electric Vehicles

Course code: **L.T.P**

Rationale:

Course Outcome:

COURSE CONTENT

Unit-I

Introduction

Definition, Components in the internet of things, Sensing and Actuation Anywhere, Anytime, Genesis of the Internet of Things, Power Sources, Internet Principles, sensor types and properties, different transducers and actuators, Internet Communications: An Overview (IP, TCP, The IP Protocol Suite (TCP/IP), UDP), IP Addresses (DNS, Static IP Address Assignment, Dynamic IP Address Assignment, IPv6), MAC Addresses, TCP and UDP Ports.

Unit-II

IoT Protocols

MQTT, XMPP, CoAP, IEEE802.15.4, ZigBee, LORA, RFID, Client Server Model, HTTP, Thing speak, AWS, Cloud MQTT.

Unit-III

IoT Security

Network and transport layer challenges, IoT Gateways, IoT Routing attacks, Fog computing, IoT Fog.

Unit-IV

Vehicle with IoT

Levels of operations, vehicle to everything, V2X paradox, VANETs, Information centric networks, CCN for VANET, three layered architecture, intelligent connected vehicles.

Unit-V

IoT Application in EV

Charging management system (CMS), smart charging, Block-chain IoT for interconnected vehicle, transportation management system, logistic management system.

Text Book

1. Precision: Principles, Practices and Solutions for the Internet of Things, Timothy Chou, TMH.

2. Designing the Internet of Things", Adrian Mc Ewen, Hakim Classically,

Wileypublication,1stEdition, November2013.

3. The Internet of Things in the Power Sector Opportunities in Asia and the Pacific, Ramamurthy, A. and Jain, P,2017.

Reference Books

1. The Internet of Things: A Survey, Journal on Networks, Luigi Atzori, Antonio Lera, Giacomo

Morabit, Elsevier Publications, October,2010.

2. The Internet of Things in the Cloud: A Middle ware Perspective, Honbo Zhou, CRCPress-2012.

3. Architecting the Internet of Things, Dieter Uckelmann, Mark Harrison, Springer,2011.

Energy Auditing and Management

Course code: **L.T.P**

Rationale:

Course Outcome:

UNIT I

GENERAL ASPECTS OF ENERGY MANAGEMENT AND ENERGY

AUDIT (7+2 Skill) 9

Commercial and Non-commercial energy - final energy consumption - energy needs of growing

economy - energy pricing - energy conservation and its importance - Re-structuring of the energy

supply sector - Energy Conservation Act 2001, Energy Conservation (Amendment) Act, 2010, and

its features - electricity tariff - Thermal Basics - need and types of energy audit - Energy

management/audit approach- understanding energy costs - maximizing system efficiencies -

optimizing the input energy requirements - energy audit instruments - Case study.

UNIT II

MATERIAL AND ENERGY BALANCE (7+2 Skill) 9

Methods for preparing process flow - material and energy balance diagrams - Energy policy

purpose - location of energy management - roles and responsibilities of energy manager –

employees training and planning- Financial Management: financial analysis techniques, simple

payback period, return on investment, net present value, internal rate of return – Case Study.

126

UNIT III

ENERGY EFFICIENCY IN THERMAL UTILITIES (7+2 Skill) 9

Introduction to fuels - properties of fuel oil, coal and gas - principles of combustion - combustion of

oil, coal and gas - Boilers: Types, combustion in boilers, performances evaluation, analysis of

losses - energy conservation opportunities - FBC boilers - Steam System: Properties of steam,

assessment of steam distribution losses, steam leakages, steam trapping, condensate and flash

steam recovery system, identifying opportunities for energy savings - Furnaces: Classification,

general fuel economy measures in furnaces, excess air, heat distribution, temperature control,

draft control, waste heat recovery – Refractory : types, selection and application of refractories,

heat loss - Cogeneration: classification and saving potentials - Case Study.

UNIT IV

ENERGY EFFICIENCY IN COMPRESSED AIR SYSTEM (7+2 Skill) 9

Compressed Air System: Types of air compressors - efficient compressor operation - Compressed

air system components - leakage test - savings opportunities - Refrigeration System: Vapour

compression refrigeration cycle – refrigerants - coefficient of performance - factors affecting

Refrigeration and Air conditioning system - savings opportunities - Vapour absorption refrigeration

system: working principle - types and comparison with vapour compression system - saving

potential - Cooling Tower: Types and performance evaluation, efficient system operation - flow

control strategies and energy saving - Diesel Generating system: Factors affecting selection -

energy performance assessment of diesel conservation avenues - Case Study.

UNIT V ENERGY EFFICIENCY IN ELECTRICAL UTILITIES (7+2 Skill) 9

Electrical load management and maximum demand control - power factor improvement and its

benefit - selection and location of capacitors - performance assessment of PF capacitors -

automatic power factor controllers - transformer losses - Electric motors: Types - losses in

induction motors - motor efficiency - factors affecting motor performance - rewinding and motor

replacement issues - energy saving opportunities with energy efficient motors - soft starters with

energy saver - variable speed drives – Fans and blowers: Types - efficient system operation - flow

control strategies -Pumps and Pumping System: Types - system operation - flow control methods -

Lighting System: Light source, choice of lighting, luminance requirements – ballast - occupancy

sensors - energy efficient lighting controls - energy conservation avenues - Case Study.

TOTAL : 45 PERIODS

SKILL DEVELOPMENT ACTIVITIES (Group Seminar/Mini Project/Assignment/Content

Preparation / Quiz/ Surprise Test / Solving GATE questions/ etc) 10

1. Study of energy conservation and audit

2. Performance study of Electric Motors.

3. Analysis on fan characteristic curves at different operating points

4. Case study of illumination system

5. Performance analysis of Compressors

TEXTBOOKS:

1. Mehmet Kanoglu, Yunus A Cengel, "Energy Efficiency and Management for

Engineers", McGraw-Hill Education, First Edition, 2020.

REFERENCES:

1. Moncef Krati, ‘Energy Audit of Building Systems: An Engineering Approach’, Third Edition,

CRC Press, Dec.2020.

2. Sonal Desai, ‘Handbook of Energy Audit’, McGraw Hill Education (India) Private Limited,

2015.

3. Michael P.Deru, Jim Kelsey, ‘Procedures for Commercial Building Energy Audits’,

American Society of Heating, Refrigerating and Air conditioning Engineers, 2011.

4. Thomas D.Eastop, 'Energy Efficiency: For Engineers and Technologists', Longman Scientific & Technical, 1990, 1st Edition.

5. 'Energy Managers and Energy Auditors Guide book', Bureau of Energy Efficiency, 2006.

6. Larry C. Witte, Philip S.Schmidt, David R.Brown, 'Industrial Energy Management and Utilization', Springer Berlin Heidelberg, 1988.

List of Open Source Software/ Learning website:

1. http://lab.fs.uni-lj.si/kes/erasmus/Energy%20Management%20Handbook.pdf

2. https://www.sciencedirect.com/science/article/pii/S2212827114004491

3. https://mppolytechnic.ac.in/mp-staff/notes_upload_photo/ CS595EnergyEfficiencyinElectricalUtilities-5391.pdf

4. http://knowledgeplatform.in/wp-content/uploads/2017/03/1.3-Energy-management-Audit.pdf

IoT in industry

Course code: **L.T.P**

Rationale:

Course Outcome:

COURSE CONTENT

Unit-I

Smart Industry

Globalization and Emerging Issues, The Fourth Revolution, LEAN Production Systems, Smart and

Unit-II

Connected Business Perspective, Smart Factories, Cyber Physical Systems and Next Generation Sensors,

Unit-III

Collaborative Platform and Product Lifecycle Management, Augmented Reality and Virtual Reality,

Unit-IV

Artificial Intelligence, Big Data and Advanced Analysis.

Architecture

Unit-V

Industrial Processes, Industrial Sensing & Actuation, Industrial Internet Systems, Business Model and

Reference Architecture, IoT Reference Architecture, Industrial IoT- Layers, Sensing, IoT Processing, IoT

Communication.

Security

Security and Fog Computing, Fog Computing in IoT, IoT Application Domains Design,

Interconnected Healthcare IoT architecture design, Open source IoT design for agricultural application,

Facility Management. Industrial IoT design based on Application Domains: Oil, chemical and

pharmaceutical and process industry.

Text Books

1. Designing the Internet of Things, Adrian McEwen, Hakim Cassimally, Wiley publication, 1st

Edition, November 2013.

2. The Internet of Things in the Power Sector Opportunities in Asia and the Pacific, Ramamurthy, A.

and Jain, P, 2017.

Reference Books

1. The Internet of Things: A Survey, Journal on Networks, Luigi Atzori, Antonio Lera, Giacomo

Morabito, Elsevier Publications, October, 2010.

2. The Internet of Things in the Cloud:A Middleware Perspective, Honbo Zhou, CRC Press-2012.

3. Architecting the Internet of Things, Dieter Uckelmann, Mark Harrison, Springer, 2011.

Cyber Security

Course code: **L.T.P**

Rationale:

Course Outcome:

Unit-I

Introduction

Introduction of Cyber Crime, Challenges of cyber crime, Classifications of Cybercrimes: E-Mail,

Unit-II

Spoofing, Spamming, Internet Time Theft, Salami attack/Salami Technique.

Web Jacking

Unit-III

Online Frauds, Software Piracy, Computer Network Intrusions, Password Sniffing, Identity Theft, cyber terrorism, Virtual Crime, Perception of cyber criminals: hackers, insurgents, and extremist group etc. Web servers were hacking, session hijacking.

Unit-IV

Cyber Crime and Criminal Justice

Concept of Cyber Crime and the IT Act, 2000, Hacking, Teenage Web Vandals, Cyber Fraud and

Cheating, Defamation, Harassment and E-mail Abuse, Other IT Act Offences, Monetary Penalties,

jurisdiction and Cyber Crimes, Nature of Criminality, Strategies to tackle Cyber Crime and Trends.

Unit-V

Indian Evidence Act

The Indian Evidence Act of 1872 v. Information Technology Act, 2000: Status of Electronic Records as Evidence, Proof and Management of Electronic Records; Relevancy, Admissibility and Probative Value of E-Evidence, Proving Digital Signatures, Proof of Electronic Agreements, Proving Electronic Messages.

Tools and Methods in Cybercrime

Proxy Servers and Anonymizers, Password Cracking, Key loggers and Spyware, virus and worms, Trojan Horses, Backdoors, DoS and DDoS Attacks , Buffer and Overflow, Attack on Wireless Networks, Phishing : Method of Phishing, Phishing Techniques.

Cloud and IoT are the latest emerging technologies and every other organization wants to implement it. Therefore, it is understandable to learn security measures under this category.

Text Books

1. Principles of Cyber crime, Jonathan Clough Cambridge University Press

2. John R.Vacca, Computer Forensics:Computer Crime Scene Investigation, 2nd Edition, Charles

River Media, 2005

Reference Books

1. Cyber Law Simplified, VivekSood, Pub: TMH.

2. Cyber Security by Nina Godbole, SunitBelapure Pub: Wiley-India

3. Information Warfare: Corporate attack and defense in digital world, William Hutchinson,

Mathew Warren, Elsevier.

4. Cyber Laws and IT Protection, Harish Chander, Pub:PHI.

5. Cryptography and Network Security: Principles and Practice, Global Edition, 7/E, William

Stallings, Pearson.

Digital System Design using FPGA

Course code: **L.T.P**

Rationale:

Course Outcome:

COURSE CONTENT

Unit-I

System Level Design

System- level architecture design for FPGAs. TMS322F series architecture.

VHDL

Unit-II

Review of VHDL programming basics, Synthesizable VHDL, synchronous and asynchronous processes, finite state machines, and memory.

Unit-III

Programming Spartan-3E using VHDL

Practical test bench design, performance testing. Counter design using Spartan 3E.

Unit-IV

Design Optimization using FPGA interface in NI-CRIO-9082

Design optimizations and performance comparison, FIFOs and streaming architectures, Analog signal processing using NI-CRIO FPGA interface.

Unit-V

Synthesis of Design Using VHDL

Design, optimize, simulate, and analyze the performance for a digital application, FPGA synthesis and iterative performance optimizations. (Xilinx software), Circuit synthesis for delay circuit design.

Text Books:

1. The Designer's Guide to VHDL, Peter J. Ashenden; HDL Chip Design, Douglas J. Smith;

2. Advanced FPGA Design Architecture, Implementation, and Optimization, Steve Kilts

Reference Books:

1. Digital System Design with FPGA, Implementation using Verilog and VHDL, Cem Unsalan,

Bora Tar.1st Edition TMH publication.

IOT Sensors and Protocols

Course code: L.T.P

Rationale:

Course Outcome:

Unit-I

Introduction to Sensor

Sensor types and properties, different transducers and actuators, IoT sensors :Temperature sensors, Proximity sensor, Pressure sensor, Water quality sensor, Gas sensor, Smoke sensor, IR sensors, Level sensors, Image sensors, Motion detection sensors, Accelerometer sensors, Gyroscope sensors, Humidity sensors, Optical sensors.

Unit-II

Communications

An Overview (IP, TCP, The IP Protocol Suite (TCP/IP), UDP), IP Addresses (DNS, Static IP Address Assignment, Dynamic IP Address Assignment, IPv6), MAC Addresses, TCP and UDP Ports.

Unit-III

IoT Protocols

MQTT, XMPP, CoAP, IEEE802.15.4, ZigBee, LORA, RFID.

Advanced Embedded Development Platforms

System on Chip (SoC), ARM®, Raspberry Pi, Evolution of Pi and technical specification comparative study, GPIO Interfacing Cloud, Analytics & UI, Client Server Model, HTTP, Thingspeak, AWS, CloudMQTT.

Unit-V

IoT framework Design

Selection of sensors for use cases, IoT end node hardware design, IoT dashboard Design for end user applications.

Text Books:

1. Designing the Internet of Things, Adrian McEwen, Hakim Cassimally, Wiley publication, 1st Edition, November 2013.

2. The Internet of Things in the Power Sector Opportunities in Asia and the Pacific, Ramamurthy, A. and Jain, P, 2017.

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2. The Internet of Things in the Cloud: A Middleware Perspective, Honbo Zhou, CRC Press-2012.

3. Architecting the Internet of Things, Dieter Uckelmann, Mark Harrison, Springer, 2011

Hydrogen and Fuel Cell Technology for Electric & Hybrid Vehicles

Course code: L.T.P

Rationale:

Course Outcome:

Unit-I

Introduction to Fuel Cells

Introduction – working and types of fuel cell – low, medium and high temperature fuel cell, liquid and methanol types, proton exchange membrane fuel cell solid oxide, hydrogen fuel cells – thermodynamics and electrochemical kinetics of fuel cells.

Unit-II

Fuel Cells for Automotive Applications

Fuel cells for automotive applications – technology advances in fuel cell vehicle systems – onboard hydrogen storage – liquid hydrogen and compressed hydrogen – metal hydrides, fuel cell control system –alkaline fuel cell – road map to market.

Unit-III

Fuel Cell Components and Their Impact on Performance

Unit-IV

Fuel cell performance characteristics – current/voltage, voltage efficiency and power density, ohmic resistance, kinetic performance, mass transfer effects – membrane electrode assembly components, fuel cell stack, bi-polar plate, humidifiers and cooling plates.

Integration of Fuel Cells in Electric Vehicles and their Performance

Hybrid electric vehicles (HEVs) and fuel cell electric vehicles (FCEVs), Integration of fuel cells with electric drive trains, Benefits and limitations of fuel cell vehicles, Performance characteristics of fuel cell vehicles,

Unit-V

Fuel efficiency and range considerations, Maintenance and servicing of fuel cell system, Diagnostics and troubleshooting in fuel cell vehicles

Economic and Policy Aspects of Hydrogen and Fuel Cell Technology

Cost analysis of fuel cell systems and hydrogen production, Government policies and incentives promoting fuel cell vehicles, Market trends and commercialization prospects, Future developments and challenges in hydrogen and fuel cell technology

Text Book

1. Fuel Cells: From Fundamentals to Applications by Supramaniam Srinivasan

2. Fuel Cells: Principles, Design, and Analysis by Jochen Valentin and Michael W. G. Hoffmann

Reference Books

1. Fuel Cell Fundamentals by Ryan P. O'Hayre, Suk-Won Cha, Whitney G. Colella, Fritz B. Prinz

2. Introduction to Hydrogen Technology, by Roman J. Press and Raymond L. Markiewicz

3. Hydrogen and Fuel Cells: A Comprehensive Guide, by Rebecca L. Wagner

4. Hydrogen and Fuel Cells: Advances in Transportation and Power, by David A. J. Rand