<u>Department of Electrical Engineering</u>

"Curriculum and Syllabi for M. Tech. in Power and Energy system Engineering (PESE)"

With effect from 2019 entry batch

Mission and Vision of the Institution

The Vision of the National Institute of Technology Silchar is establishing unique identity by development of high quality human and knowledge resources in diverse areas of technologies to meet local, national, and global economic and social need and human society at large in self-sustained manner.

The mission of National Institute of Technology Silchar is to train and transform young men and women into responsible thinking engineers, technologists and scientists, to motivate them to attain professional excellence and to inspire them to proactively engage themselves for the betterment of the society.

Mission and Vision Statement
of
Electrical Engineering Department

The mission of the Electrical Engineering Department is to impart quality education to our students and provide a comprehensive understanding of electrical engineering, built on a foundation of physical science, mathematics, computing and technology and to educate a new generation of Electrical Engineers to meet the future challenges.

The Vision of Electrical Engineering Department is to be a model of excellence in technical education and research by producing world-class graduates who are prepared for life-long engagement in the rapidly changing fields of electrical and related fields.

Program Educational Objectives (PEOs)

PEO1: The postgraduates of P&ESE will demonstrate their outstanding education skills that will enable them to integrate undergraduate fundamentals with the knowledge acquired to evaluate and analyze new developments in Power and Energy industry.

PEO2: The postgraduates of P&ESE will demonstrate advancement in engineering skill to engage in perpetual learning to undertake significant research and or developmental projects even in multidisciplinary environment to meet the societal requirements.

PEO3: The P&ESE postgraduates will demonstrate their professional, ethical and social issues and show respect for diversity and global issues for successful professional career.

PO Statements (POs):

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 of Power and Energy System. The mastery should be at a level higher than the requirements in the bachelor program of Electrical Engineering.

PO4: students should be able to work independently/ in a team with high ethical values towards social, environmental and economic issues.

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Course Structure

Semester I

S. N.	Code	Subject	L	T	P	Credits
1	EE 5201	Power system analysis	3	0	0	3
2	EE 5202	Non-conventional energy source and energy converter	3	0	0	3
3	EE 5203	Power system protection	3	0	0	3
4	EE 5204	Power systems laboratory	0	0	3	2
5	EE 5210	Seminar-I	0	0	2	1
6	EE 52XX	Elective – I	3	0	0	3
7	EE 52XX	Elective – II	3	0	0	3
		Total contact hours/credits	15	0	5	18

Semester II

S. N.	Code	Subject	L	T	P	Credits
1.	EE 5211	Power System dynamics and control	3	0	0	3
2.	EE 5212	Power System Optimization	3	0	0	3
3	EE 5213	Modelling and Control of Sustainable Energy System	3	0	0	3
4.	EE 5214	Energy laboratory	0	0	3	2
5.	EE 5215	Seminar-II	0	0	2	1
6.	EE 52XX	Elective – III	3	0	0	3
7.	EE 52XX	Elective – IV	3	0	0	3
8.	EAA	Extra Academic Activities (Yoga)	0	0	2	0
		Total contact hours/credits	15	0	7	18

Semester: III and IV

S. N.	Code	Subject	L	T	P	Credits	Semester
1	EE 6298	Project Phase -I	-	-	-	06	III
2	EE 6299	Project Phase -II	-	-	-	08	IV
		Total contact hours/Credits	-	-	-	14	---

Electives I & II

S. N.	Code	Subject	*Prerequisites, if any*
1.	EE 5231	Energy, ecology and environment	
2.	EE 5232	HVDC and FACTS devices	
3	EE 5233	Power quality	
4.	EE 5234	Energy policy and planning	
5.	EE 5235	Instrumentation and control in energy system	
6.	EE 5236	Embedded system and application	

7.	EE 5237	Smart grid	
8.	EE 5238	Modelling and analysis of electrical machines	
9.	EE 5239	Power Quality in Power Distribution Systems	
10.	EE 5240	Soft computing techniques and applications	

Electives III & IV

S. N.	**Code**	**Subject**	***Prerequisites, if any***
1.	EE 5241	Power electronic device and DC converters	
2.	EE 5242	Intelligent algorithms for electric system	
3	EE 5243	Distribution automation	
4.	EE 5244	Restructured electricity markets	
5.	EE 5245	Quantitative methods for energy management and planning	
6.	EE 5246	Energy conservation and management	
7.	EE 5247	Power system reliability	
8.	EE 5248	Parameter estimation and system identification	
9.	EE 5249	Power system transients	
10.	EE 5250	Electrical networks and pricing	

Detailed Syllabi

EE 5201	**Power System Analysis**	L T P C
	M. Tech. (PESE), First Semester (Core)	**3 0 0 3**

Pre-requisites: Power Systems.

Module-1: Z_{BUS} building algorithm: modification due to network changes, Analysis of Series and shunt Faults on digital computers.

Module-2: Power flow studies: AC/DC load flow, solution of ill conditioned systems, Continuation Power Flow.

Module-3: Contingency Evaluation: Necessity of contingency evaluation in power systems, Contingency Ranking, methods of distribution factors for line and generator outages, calculation of PTDF & LODF.

Module-4: Reliability Analysis: Representation of power system components for reliability analysis, Loss of Load Expectation (LOLE), Frequency and duration approach.

Module-5: State Estimation: Static as well as dynamic

Text and Reference Books:

Power System Analysis, John J. Grainger, William D Stevenson, Tata McGraw Hill.
Computer Methods in Power System Analysis, G. W. Stagg, El-Abaid,Tata McGraw Hill.
Computer Techniques in Power System Analysis,M. A. Pai,Tata McGraw Hill.
Power Generation, Operation and Control, Allen J. Wood and Bruce F. Wollengerg,Wiley.

Course Outcomes: At the end of this laboratory, students will be able to:

1. define the Power System Analytical (PSA) problems, such as: load flow study, Zbus formulation, fault, contingency & reliability analysis, State Estimation etc.
2. describe the usefulness of each analytical techniques.
3. demonstrate the computing procedure to solve each of the PSA problem.
4. assess the computational complexities involved in the solution process.

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EE 5202	Non-conventional energy source and energy converter	L	T	P	C
	M. Tech. (PESE), First Semester (Core)	**3**	**0**	**0**	**3**

Energy scenario, review of various energy sources, importance of non-conventional sources such as solar, biogas, wind, tidal, OTEC etc. Study of typical energy converters such as high-performance motors, special generators driven by biogas engines, wind turbines, etc. mini-hydro generators, modern state-of-the-art and futuristic systems in this area.

Texts and reference materials:

1. G D Rai, Non-Conventional Sources of Energy, Khanna Publishers, 2004.
2. Chetan Singh Solanki, 'Solar Photovoltaics-Fundamentals, Technologies and Applications', PHI Learning Pvt. Ltd., New Delhi, 2011.
3. Thomas Ackermann, Wind Power in Power Systems, John Wiley & Sons ltd.
4. Godfrey Boyle, Renewable Energy –power for a sustainable future, Published by Oxford University Press, 2004.
5. John Twidell and Tony Weir, Renewable Energy Resources, Taylor and Francis Group 2007.
6. Dr. N K Giri, Alternatie Energy-Sources, Applications and Technologies, Khanna Publishers, 2012.

Course Outcomes: At the end of this laboratory, students will be able to:

1. understand the global energy scenario and the potential of renewable energy sources to address the global energy problem.
2. explain the working non-conventional energy technologies to generate electricity
3. design a sub-system of electrical engineering.
4. recognize the need and ability to engage in lifelong learning for further developments in the field of non-conventional energy.

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EE 5203	Power system protection	L	T	P	C
	M. Tech. (PESE), First Semester (Core)	**3**	**0**	**0**	**3**

Module-1: Fundamentals of protection practice: Purpose of Power system protection, Protective gear, reliability, selectivity, zone of protection, stability, sensitivity, primary and backup protection, some commonly used definitions and terminology, relay contact systems, relay tripping circuits, unit and non-unit types of protection

Module-2: Current and potential transformers (CTs and PTs): Introduction to CTs and Pts, Errors in CTs and PTs, voltage factors, protection of PTs, residually connected PTs, transient performance of PTs, capacitor voltage transformers, turn compensation in CTs, composite errors in CTs, accuracy limit of Protective CTs

Module-3: Protective relaysand circuit breakers: Introduction to relays, types of relays,types of measurements**,** static relays, circuits using digital and analogue techniques, types of circuit breakers (CBs), arc extinction, recovery voltage, re-striking voltage, fault clearing process, trip circuit of CB, miniature CB, moulded case CB, numerical protection, microprocessor based numerical relays, artificial intelligence based numerical relays, adaptive relaying.

Module-4: Protection of transformer:Nature of winding connections and types of transformer fault,magnetizing current inrush, overheating protection, overcorrection protection, restricted earth fault protection, differential protection and its various types, use of interposing CTs, autotransformer protection

Module-5: Protection of generator:Types of generator faults, winding protection, various schemes of protection, inter turn protections schemes, overload and over current protection, un balanced loading, negative sequence protection, rotor fault and rotor protection

Module-6: Transmission line protection:Principle of distance protection**,** voltage limit for accurate reach point measurement, zone of protection, distance relay type and their applications, distance protection schemes

Module-7: Protection of motors:Bearing failures, heating of winding, overload protection, stalling of motors, stator protection, phase unbalanced relays, rotor protection

Module-8: Protection of capacitors, rectifier, thyristors, reactors

Reference Books:

1. General Electric Company, Protective relaying Application Guide, GE C measurements
2. Badri Ram, D.N. Vishwakarma, Power system Protection and switchgear, Mc Graw Hill Education (India) Private Ltd
3. S.S. Rao, Switchgear Protection and power systems, Khana Publisher
4. J.B. Gupta, Switchgear and Protection, Katson Books

Course Outcomes: At the end of this course, students will be able to:

1. describe various terminologies, principles of power system protection schemes.
2. categorize various switchgear components, types of relaying systems, and protection schemes.
3. select and apply various protection schemes for machines, transmission line, cables, reactors, capacitors, rectifiers and thyristors.
4. design various protection schemes and to evaluate the size of switchgear components for power plant equipment

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EE 5204	Power System Laboratory	L	T	P	C
	M. Tech in Power and Energy System Engineering	0	0	3	2
	Electrical Engineering Branch				

Pre-requisites: Power System

Experiment -1(a): Solution of Economic Load Dispatch problem neglecting both transmission losses and generating limits.

Experiment -1(b): Solution of Economic Load Dispatch problem considering generating limits and neglecting transmission losses.

Experiment -2: Solution of Economic Load Dispatch problem considering both transmission losses and generating limits.

Experiment -3(a): Formation of bus admittance matrix for a given power system network without considering transformers.

Experiment -3(b): Formation of bus admittance matrix for a given power system network considering transformers.

Experiment -4: Load Flow Analysis using various solution approaches using MiPower/ ETAP/ MATPOWER, etc.

Experiment -5(a): Short circuit studies on Power TLS Fault Simulator.

Experiment -5(b): Short circuit studies using MiPower software.

Experiment -6: Formation of Zbus by Zbus building algorithm.

Experiment -7: Study of micro-controller based earth fault relay characteristics.

Experiment -8: Study of micro-controller based over current relay characteristics.

Experiment -9: Study of impedance relay characteristics using Power TLS Simulator.

Experiment -10: Solution of Load Frequency and Voltage Control in power systems.

Text and Reference Books:

Sl. N.	Name of Books	Authors	Publishers
1.	Fundamentals of power system economics	D. Kirschen & G. Strbac	John Wiley & Son's Ltd
2.	Power Generation, Operation and Control	Allen J. Wood and Bruce F. Wollengerg	John Wiley & Son's ltd.

3.	Power System Analysis	Hadi Saadat	PSA Publishing
4.	Power System Analysis	John J. Grainger, William D Stevenson	Tata McGraw Hill.
5.	Computer Techniques in Power System Analysis	M. A. Pai	Tata McGraw Hill.

Course Outcomes (Cos): At the end of this lab, students will be able to:

1 **relate** various power systems computational works.
2 **compute** basic power system economic load dispatch problems.
3 **use** industry relevant software tools to solve power flow problems, short circuit studies, load frequency and voltage control of power system networks.
4 **apply** SCADA based hardware models to analyze power system performances.
5 **use** various relays for power system protection

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EE 5210	SEMINAR I	L	T	P	C
	M. Tech. (PESE), First Semester	0	0	2	1

Course Outcome of Seminar:

At the end of seminar course, students are expected to be able to:

1. Prepare good slides and present a particular topic effectively.
2. Develop team spirit and leadership qualities through group activities.
3. Develop confidence for self-learning and overcome the fear of public presentations.
4. Update knowledge on contemporary issues, prepare technical report and do presentations on these issues.
5. Learn technical editing software Latex and write technical report using Latex.

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EE 5231	**Energy, ecology and environment**	L	T	P	C
	M. Tech. (PESE), First Semester (Elective I & II)	**3**	**0**	**0**	**3**

Topics Covered: Origin of the earth, Earth's temperature and atmosphere. Sun as a source of energy, nature of its radiation. Biological processes, photosynthesis. Food chains. Marine ecosystem. Ecosystem theories. Autecology's, sources of energy, classification of energy sources, quality and concentration of an energy source, characteristics temperature. Fossil fuels: coal, oil, gas, geothermal, tidal and nuclear energy. Solar, wind, hydropower, biomass. Resources of energy and energy use pattern in different regions of the world. Environmental degradation, primary and secondary pollutants. Thermal and radioactive pollution, air and water pollution. Micro climatic effects of pollution. Pollution from stationary and mobile sources. Biological effects of radiation, heat and radioactivity disposal. Pollution abatement methods.

Reference Books:

1. D. H. Meadows, D.L. Meadows, J. Randry nd W.W. Behrens, Limits to Growth, Universe Books, New York, 1972.
2. Introduction to Environmental Engineering and Science (IInd edition) by Gilbert M. Masters, Prentice Hall of India Private Limited 1998.
3. Environmental Science by G. Ryler Miller Jr.
4. Air Pollution Control Engineering by De Nevers

Course Outcomes: At the end of this course, students will beable to:

1. demonstrate knowledge of new and renewable energy and their relationship with ecology & environment.
2. describe conventional and non-conventional energy scenario with respect to the environment.
3. explain the Environmental Pollution and their effects on the environment
4. design and develop suitable energy generation technologies on future demand.

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EE 5232	HVDC and FACTS devices	L	T	P	C
	M. Tech. (PESE), First Semester (Elective I & II)	**3**	**0**	**0**	**3**

Topics Covered:

HVDC Transmission System:

Module-1: General aspects and comparison of AC and DC Transmission, Application of DC Transmission, Description of DC Transmission System: Types of DC Links, Converter stations, Different configurations for asynchronous interconnection, Modern trends in HVDC Technology

Module-2: Analysis of HVDC Converters: Line commutated converters(LCC): Various possible configurations 6 pulse converters and its generalization, Choice of optimum HVDC converter configuration based on desired features; Analysis of Graetz bridge neglecting overlap (both rectifier and inverter mode operation), Analysis of Graetz bridge with overlap (both rectifier and inverter mode operation) with two and three valve conduction mode, three and four valve conduction mode; LCC bridge characteristics and boundary for rectifier and inverter operations; Analysis of 12-pulse bridge converter configuration

Module-3: Control philosophy of HVDC-link: Principle of DC link control, Converter control characteristics (both for rectifier and inverter end), Power flow controller characteristics (forward and reverse power flow), HVDC system control hierarchy, starting and stopping of DC link

FACTS Devices:

Module-4: General description of flexible transmission system controllers and its various classification, A general equivalent circuit for FACTS controllers and their constraint equations and control variables, benefits with the application of FACTS controllers, Application of FACTS controllers (Custom Power Devices) in distribution systems.

Module-5: AC transmission line and reactive power compensation: Analysis of uncompensated line, performance of line connected to unity PF load, Performance of a symmetrical line, Concept of series and shunt passive reactive power compensation, Compensation by series and shunt capacitor at midpoint of line using equivalent circuit model and comparison between them. Compensation by STATCOM and SSSC at the midpoint of the line using equivalent circuit model and comparison between them.

Module-6: Static Var Compensator (SVC): Analysis of SVC connected at the midpoint of line, control characteristic of SVC, Expression of voltage and power flow in control range and at SVC limit, Power angle curve for SVC, SVC configurations, Thyristor Controlled Reactor (TCR), Thyristor Switched Reactor (TSR), Thyristor Switched Capacitor (TSC), Modeling of SVC and its equivalent circuit, Application of SVC

Module-7: Thyristor and GTO Controlled Series Capacitor (TCSC and GCSC): Basic concepts of controlled series compensation (TSSC, TCSC and GCSC, GSSC), operating modes in a TCSC, Analysis of TCSC, Control functions of TCSC, Analysis of GCSC, Mitigation of SSR with TCSC and GCSC

Module-8: Static Phase Shifting Transformer (SPST): Basic principle of a PST and its equivalent circuit representation, schematic diagram of a SPST, configurations of SPST, Improvement of transient stability using SPS, Applications of SPST

Module-9: Static Synchronous Compensator (STATCOM): Principle of operation of STATCOM and its control characteristics, Simplified analysis of a 3-phase 6-pulse STATCOM using switching functions, Multi-pulse and Multi-level STATCOMs, Applications of STATCOM

Module-10: Static Synchronous Series Compensator (SSSC): Operation of SSSC and the control of power flow, Power flow control characteristics, SSSC with an Energy source: Active and reactive voltage control, Power flow with constant active and reactive voltage injection in the line.

Module-11: Unified Power flow Controller (UPFC): Analysis of operation of a UPFC connected at the sending end/ at the receiving end/ at the midpoint, Schematic concept of IPFC, BTB HVDC link and Convertible Static Compensator (CSC).

Reference Books:

1. K R Padiyar, HVDC Power Transmission Systems, New Age International
2. K R Padiyar, FACTS Controllers in Power Transmission and Distribution, New Age International
3. Narain G. Hingorani and Laszlo GyuGui, Understanding FACTS Concepts and Technology of Flexible AC Transmission Systems, IEEE Press
4. Vijay K. Sood, HVDC and FACTS Controllers Applications of Static Converters in Power Systems, Springer
5. Arindam Ghosh and Gerard Ledwich, Power Quality Enhancement Using Custom Power Devices, Kluwer Academic Publishers Boston / Dordrecht / London

Course Outcomes: At the end of this course, students will be able to:

1. understand the HVDC transmission and FACTS technologies with their application benefits
2. classify HVDC systems and FACTS controllers configurations
3. analyse HVDC converters and FACTS controllers with relevant waveforms and characteristics
4. describe the control philosophy of HVDC-link and various FACTS controllers

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EE 5233	Power Quality	L T P C
	M. Tech. (PESE), First Semester (Elective I & II)	**3 0 0 3**

Topics Covered:

Module-1: Overview and definition of Power Quality (PQ), classification and characteristics of different PQ problems, Sources of Pollution, International PQ standards and regulations, Power Acceptability curves- their necessity and utilization.

Module-2: Voltage Sag, swell, transients and interruptions. – Characteristics, causes, effects and methods of mitigation. Voltage sag performance evaluations for transmission and distribution systems. Role of energy storage devices in mitigating poor voltage quality. Reliability indices and their importance.

Module-3: High voltage transients in power systems- their causes, effects and methods of reduction. Ferro-resonance, its effect, mitigation and ways of detection of its occurrence. Devices for overvoltage protection and electrical noise.

Module-4: Harmonics – Causes, effects, methods of quantitative analysis of voltage and current harmonics contamination in their respective waveforms. Relation between true power factor, displacement power factor and distortion factor and harmonic phase sequences. Waveform analysis of harmonic injection due to different non-linear loads. Harmonic Resonance – their causes, effects and mitigation. Effects of harmonics on different power system components.

Module-5: Applied Harmonics – Choice of PCC, harmonic evaluations on utility systems, principles for controlling harmonics in utility distribution systems and end user facility. PQ standards regarding harmonics in particular and PQ benchmarking.

Reference Books:

1. Math H. J. Bollen, Understanding Power Quality, IEEE Press
2. Roger C. Dugan et.al, Electrical Power Systems Quality, McGraw Hill
3. Arindam Ghosh and Gerard Ledwich, Power Quality Enhancement Using Custom Power Devices, Springer

Course Outcomes: At the end of this course, students will be able to:

1. **analyse** the causes of different PQ problems and the extent to which they affect different sensitive loads.
2. **identify** a particular PQ problem based on their characterization and evaluate the optimum solution as mitigation scheme.
3. know how to **mitigate** practical problems faced in case of voltage sags and transient voltages in the system and the challenges by suggesting the optimal solutions to such problems.
4. know how to **identify** the adverse effects of non-linear loading at the distribution end and different ways of eliminating system harmonics.
5. known how to **apply** the knowledge of international PQ standards and PQ benchmarking of sensitive loads and also to keep themselves updated to those**.**

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EE 5234	**Energy policy and planning**	L	T	P	C
	M. Tech. (PESE), First Semester (Elective I & II)	**3**	**0**	**0**	**3**

Topics to be covered:

Module-1: Energy (and power) policies in the country and global energy policy, Tariffs and Subsidies.

Module-2: Energy utility interface; Private sector participation in power generation; State role and fiscal policy.

Module-3: Energy and development; National energy plan; Role of modeling in energy policy analysis.

Module-4: Energy data base; Energy balances; Flow diagrams; Reference energy system.

Module-5: Energy demand analysis; Trend analysis, Econometric models; Elasticities approach; Input-Output models.

Module-6: Energy demand supply balancing; Energy economy interaction; Energy investment planning; Energy environment interaction, Energy Pricing.

Reference Books:

1. Power System Economics, Steven Stoft, Willey Inter-Science
2. Alternating Current: Electricity Markets and Public Policy, T.J. Brennan, K. Palmer and S.A. Martinez.
3. Electricity Sector in India: Policy and Regulation, Alok Kumar, OUP India,
4. Mapping Power: The Political Economy of Electricity in India’s States edited by Navroz K. Dubash, Oxford.
5. Energy for Sustainability: Technology, Planning, Policy by John Randolph, Gilbert M. Masters, Island Press, 1718, Connecticut Ave, NW, Suite 300, Washington, D.C. 20009.
6. The Economics of Electricity Markets, by Darryl R. Biggar, Mohammad Reza Hesamzadeh, Wiley
7. Electric Power Distribution by A. S. Pabla, Tata McGrawHill Publishing, New Delhi.

Course Outcomes:

At the end of the course, students should be able to:

1. understand how energy policy is designed and implemented;
2. identify policy processes;
3. identify the role of different stakeholders;
4. formulate analytical strategy, collect necessary data, and perform analysis on energy policy-related problems; and
5. understand how energy policy instruments affect energy system investment decisions and public behavior.

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EE 5235	Instrumentation and control in energy system M. Tech. (PESE), First Semester (Elective I & II)	L T P C 3 0 0 3

Module-1: Overview of Instruments and Measurement Systems: Principles of measurements and measurement errors, Classification of instruments, static and dynamic characteristics, Input output configurations of measurement systems.Instruments for measuring pressure, temperature, velocity and flow, heat flux, liquid level and concentration in energy systems.Characterization of combustors, Flue gas analysers, Exhaust gas analysers, Solar energy measurement requirements and instruments, Net Metering.Meteorological data measurements, Energy auditing instruments, Energy audit kit, Humidity measurement.

Sensor and transducers: Types, characteristics and applications of Mechanical transducers, Types, characteristics and applications of electrical transducers, Principles of Modern sensors and typical applications.

Module-2: Introduction to Control Systems: Overview of control systems, types and components, Feedback and non-feedback systems and their applications, Transfer function, block diagram representation and reduction techniques.

Signal conditioning: Operational amplifier, types and characteristics, application, circuits- inverter, adder, substractor, multiplier and divider, A/D and D/A conversion techniques.

Data Acquisition Systems: Types of Instrumentation Systems and components, Working principle and application of Single channel A /D converter, Working principle and application of multi-channel A/D converter, Digital data processing and display.

Module-3: Microcontrollers and compilers: Overview of microprocessor and microcontroller, architecture. Use of compilers for data acquisition, processing and display, typical microcontroller Applications for monitoring and control of electrical andnon–electrical parameters/processes.

Text Books:

1. Morris A. S., Principles of Measurements and Instrumentation, Prentice Hall of India, 1998
2. Sawhney A. K., A Course in Electrical and Electronics Measurements and Instrumentation, Dhanpat Rai, 2011
3. Murty D.V.S., Transducers and Instrumentation, Prentice-Hall of India Pvt. Ltd. 1995
4. Ogata K., Modern Control Engineering, Prentice Hall, 1997

Reference Books:

1. Bentley J. P., Principles of Measurement Systems, Fourth Edition, Pearson Prentice Hall, 2005
2. Jain R. P., Modern Digital Electronics, McGraw Hill, 1998
3. Gaonkar R., Microprocessor Architecture, Programming and Applications with 8085, Penram International Publishing, 2012
4. Raman C. S., Sharma G. R., and Mani V. S. V., Instrumentation Devices and systems, Tata McGraw Hill, 1983
5. Holman J.P., Experimental methods for engineers Sixth edition, McGraw-Hill .1994

Course Outcomes: At the end of the course the students will be able to

1. analyze working of different measuring instruments.
2. select and utilize relevant transducers in the design process.
3. design appropriate control system as per the requirement.
4. apply their concept to build corresponding signal conditioning and data acquisition systems along with the embedded computing platform.

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EE 5236	**Embedded system and application**	L	T	P	C
	M. Tech. (PESE), First Semester (Elective I & II)	**3**	**0**	**0**	**3**

Topics Covered:

Module-1: Introduction to Embedded systems: Single purpose hardware and software. Architectural Issues: CISC, RISC, DSP Architectures. Component Interfacing: Interrupt.

Module-2: DMA, I/O Bus structure, I/O Devices. Software for Embedded systems: Program design and Optimization techniques, O.S for Embedded Systems, Real time issues. Designing Embedded systems: Design issues, Hardware software co-design, use of UML. Embedded control Applications: open loop and closed loop control

Module-3: Software coding for PID Controller, applications- washing machines, automobiles. Networked Embedded systems: Distributed Embedded Architectures, Protocol design issues, wireless network. Embedded Multimedia and Telecommunication Applications: Digital camera, Digital TV, set top box, voice and video telephony.

Reference Books:

1. W. Wolf, Computers as components: Principles of embedded computing system design, Elsevier, 2008
2. R. Gaonkar, Fundamentals of Microcontrollers and Application in Embeded Systems, Penram International Publishing, 2015
3. Kenneth J. Ayala, The 8051 Microcontroller, Thomson
4. Labrosse, Embedding System Building Blocks, CMP Publisher
5. Raj Kamal, Embedded Systems, TMH
6. Ajay V. Deshmukhi, Microcontrollers, TMH
7. Frank Vahid, Tony Givargis, Embedded system design, John Wiley
8. Raj Kamal, Microcontrollers, Pearson Education
9. David E. Simon, An Embedded software Primer, Pearson Education

Course Outcomes: At the end of this course, students will be able to:

1. understand Embedded systems and the interface issues related to it
2. analyze about different models on embedded systems
3. describe about the real time models, languages and operating systems
4. analyze real time applications, obstacles and solutions.

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EE 5237	**Smart grid**	L T P C
	M. Tech. (PESE), First Semester (Elective I & II)	**3 0 0 3**

Module-1: Smart Grid Structure (7 hrs): Definition, Various components, Smart Grid architecture, Application and standards, Distributed Generation
Module-2: Communication Technologies for Smart Grid (7 hrs): Data communication, Communication Channel, Layered architecture and Protocols, Smart Grid communication layers
Module-3: Advanced Monitoring Infrastructure (6 hrs): Smart meters, Wide area monitoring system, Phasor measurement units, SCADA
Module-4: Demand Side Management (6 hrs): Definition, Impact analysis of DSM, load curve, Energy consumption scheduling, Controllable load models and challenges
Module-5: Microgrid Protection (6 hrs): Mode of microgid operations, Islanding detection of microgrid, Protection issues of microgrid
Module-6: Cyber Security in Smart Grid (4 hrs): Possible threats and cyber security challenges in smart grid, Security of Information

Books:

1. Smart Grid: Fundamentals of design and analysis by James Momoh (John Wiley & Sons publisher).
2. Smart Grid: Technology and applications by J. Ekanayake, N. Jenkins, K. Liyanage K, J. Wu, A. Yokoyama (Wiley publication).
3. Power Generation Operation and Control by A. J. Wood, B. F. Wollenberg (John Wiley & Sons publisher).

Course Outcomes (Cos):

At the end of this laboratory, students will be able to:

1. explain the operation and intermittent nature of renewable energy sources.
2. analyze smart grid structure including, technologies, components, standards used and applications.
3. apply knowledge to develop demand side management strategy

inspect the cyber security issues of smart grid and protection aspects of micro grid.

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EE 5238	Modelling and analysis of electrical machines	L	T	P	C
	M. Tech. (PESE), First Semester (Elective I & II)	**3**	**0**	**0**	**3**

Topics Covered:

Module-1: Principles of Electromagnetic Energy Conversion, General expression of stored magnetic energy - Energy State Functions. Modelling of Electromechanical systems - Basic Concepts of Rotating Machines-Calculation of air gap mmf and per phase machine inductance using physical machine data.

Module-2: Different methods of Transformation – Phase Variable Form, Instantaneous Symmetrical Component Techniques, Reference Frame Theory (Different Reference Frames and Transformation between Reference Frames)

Module-3: Basic Performance Equations and Analysis of different Rotating Machines - DC Machines, Synchronous and Induction Machines.

Module-4: DC Machines - Voltage & Torque Equations, Basic types of DC Machines, Dynamic Characteristics of Permanent Magnet and DC Shunt Motors and solution using Laplace Transformation.

Module-5: Synchronous and Induction Machines - Three phase symmetrical induction machine and salient pole synchronous machines in phase variable form, Application of reference frame theory to three phase symmetrical induction and synchronous machines, Dynamic direct and quadrature axis model in arbitrarily rotating reference frames. Determination of Synchronous machine dynamic equivalent circuit parameters. Analysis and dynamic modeling of two phase asymmetrical induction machine and single phase induction machine.

Module-6: Transients in electrical machines - Switching Transients and surges. Transient and short circuit studies on alternators, Run-up re-switching and other transients in Induction Machines.

Module-7: Modelling of Special Machines - Permanent magnet synchronous machine, Surface permanent magnet (square and sinusoidal back emf type) and interior permanent magnet machines - Construction and operating principle - Dynamic modeling and self-controlled operation.Analysis of Switch Reluctance Motors. Brushless D.C. Motors. Recent trends.

Reference Books:

1. Electric Machinery, Charles Kingsle, Jr., A.E. Fitzgerald, Stephen D.Umans, Tata Mcgraw Hill.
2. Electric Motor & Drives: Modeling, Analysis and Control, R. Krishnan, Prentice Hall of India.
3. Brushless Permanent Magnet and Reluctance Motor Drives, T.J.E. Miller, Clarendon Press.
4. Analysis of Electric Machine, P.C.Krause, Wiley IEEE Press 3rd Edition.

Course Outcomes: At the end of this laboratory, students will be able to:

1. analyze basic concepts of rotating machines.
2. construct machine models based on different reference frames.
3. synthesize equivalent circuit parameters for synchronous and asynchronous machines.
4. analyse special machines.

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EE 5239	Power Quality in Power Distribution Systems M. Tech. (PESE), First Semester (Elective I & II)	L	T	P	C
		3	**0**	**0**	**3**

Topics Covered:

Module-1: SINGLE PHASE CIRCUITS: POWER DEFINITIONS AND COMPONENTS:
Introduction, Power Terms in a Single-Phase System, Sinusoidal Voltage Source Supplying Non-linear Load Current, Non-sinusoidal Voltage Source Supplying Non-linear Loads, Active Power, Reactive Power, Apparent Power, Non-Active Power, Distortion Power, Fundamental Power Factor, Power Factor

Module-2: THREE PHASE CIRCUITS: POWER DEFINITIONS AND VARIOUS COMPONENTS:
Three-phase Sinusoidal Balanced System, Balanced Three-phase Circuits, Three Phase Instantaneous Active Power, Three Phase Instantaneous Reactive Power, Power Invariance in abc and dq0 Coordinates, Instantaneous Active and Reactive Powers for Three-phase Circuits, Three-Phase Balance System, Three-Phase Unbalance System, Symmetrical components, Effective Apparent Power, Positive Sequence Powers and Unbalance Power, Three-phase Non-sinusoidal Balanced System, Neutral Current, Line to Line Voltage, Apparent Power with Budeanu Resolution: Balanced Distortion Case, Effective Apparent Power for Balanced Non-sinusoidal System, Unbalanced and Non-sinusoidal Three-phase System, Arithmetic and Vector Apparent Power with Budeanu's Resolution, Effective Apparent Power

Module-3: FUNDAMENTAL THEORY OF LOAD COMPENSATION:
Introduction, Fundamental Theory of Load Compensation, Power Factor and its Correction, Voltage Regulation, An Approximation Expression for the Voltage, Some Practical Aspects of Compensator used as Voltage Regulator, Phase Balancing and Power Factor Correction of Unbalanced Loads, Three-phase Unbalanced Loads, Representation of Three-phase Delta Connected Unbalanced Load, An Alternate Approach to Determine Phase Currents and Powers, An Example of Balancing an Unbalanced Delta Connected Load, A Generalized Approach for Load Compensation using Symmetrical Components, Sampling Method, Averaging Method, Compensator Admittance Represented as Positive and Negative Sequence, Admittance Network

Module-4: CONTROL THEORIES FOR LOAD COMPENSATION:
Introduction, State Space Modelling of the Compensator, Switching Control of the VSI, Generation of P_{loss} to maintain dc capacitor voltage, Computation of load average power (P_{lavg}), Some Misconception in Reactive Power Theory, Theory of Instantaneous Symmetrical Components, Compensating Star Connected Load, Compensating Delta Connected Load

Module-5: SERIES COMPENSATION: VOLTAGE COMPENSATION USING DVR:
Introduction, Conventional Methods to Regulate Voltage, Dynamic Voltage Restorer (DVR), Operating Principle of DVR, General Case, Mathematical Description to Compute DVR Voltage, Transient Operation of the DVR, Operation of the DVR With Unbalance and Harmonics, Realization of DVR voltage using Voltage Source Inverter, Maximum Compensation Capacity of the DVR Without Real Power Support from the DC Link

Reference Books:

1. Power Quality Enhancement Using Custom Power Devices, Arindam Ghosh and Gerard Ledwich, Kluwer Academic Publishers Boston / Dordrecht / London.
2. Reactive power control in electric systems, T. J. E. Miller, Wiley, 1982.
3. NPTEL Course on "Power Quality in Power Distribution Systems", Mahesh Kumar.

Course Outcomes: At the end of this course, students will be able to:

(1) understand single and three phase circuits power conditions and components

(2) analyze fundamental theories of load compensation

(3) model and develop control technique of the compensator for load compensation

(4) realize the shunt and series compensator under unbalance and harmonic

EE 5240	Soft Computing Techniques and Applications	L	T	P	C
	M. Tech. (PESE), First Semester (Elective I & II)	**3**	**0**	**0**	**3**

Module-1: INTRODUCTION TO SOFT COMPUTING TECHNIQUES
Introduction to intelligence, biological intelligence, artificial intelligence (AI), computational intelligence. Evolution of computational intelligence, from conventional AI to computational intelligence, soft computing constituents, machine learning basics, overview of soft computing techniques, intelligent decision systems.

Module-2: EVOLUTIONARY ALGORITHMS
Introduction to genetic algorithm, genetic operators and parameters, genetic algorithms in problem solving, theoretical foundations of genetic algorithms, evolutionary programming, particle swarm optimization, differential evolution; implementation issues and application for solving problems.

Module-3: ARTIFICIAL NEURAL NETWORKS
Neural model and network architectures, basic-concepts-single layer perception-Multi layer perception, supervised and unsupervised learning, back propagation networks, associative learning, competitive networks, Hopfield network, computing with neural nets and applications of neural networks.

Module-4: FUZZY SYSTEMS
Introduction to fuzzy sets, operations on fuzzy sets, fuzzy relations, fuzzy measures, rule matrix, application of fuzzy set theory to different branches of science and engineering.

Module-5: EA-NEURO-FUZZY MODELLING
Hybridization of EAs, Fuzzy and ANNs for increased intelligence for solving complex real-life problems.

Text Books:

1. Genetic Algorithms in Search, Optimization, and Machine Learning, D. E. Goldberg, Addison-Wesley.
2. Neural Networks- A Comprehensive Foundation, S. Haykin, PH.
3. Neural Networks- A Classroom Approach, Satish Kumar, TMH.
4. Fuzzy Sets and Fuzzy Logic: Theory and Applications, G. J. Klir, and B. Yuan, PH.

Reference books:

1. Genetic Algorithms+ Data Structures = Evolution Programs, Z. Michalewicz, Springer-Verlag.
2. Soft Computing & Intelligent Systems: Theory & Applications, N.K. Sinha & M. M. Gupta(Eds), Academic Press.
3. Neural Network Design, M.T. Hagan, H. B. Demuth, and M. Beale, Thompson Learning.
4. Neural Networks, C. Lau (Ed), IEEE Press.
5. Fuzzy Set Theory and Its Applications, H. J. Zimmerman, Academic Press.

Course Outcomes: At the end of this course, students will be able to:

1. use evolutionary algorithms for solving non-linear optimization problems.
2. develop solutions using fuzzy logic for systems with imprecise information and complex models.
3. develop solutions for solving complex problems using appropriate artificial neural networks.
4. develop intelligent solutions for complex problems using hybridization of EAs, Fuzzy and ANNs

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EE 5211	**Power System dynamics and control**	L T P C
	M. Tech. (PESE), Second Semester (core)	**3 0 0 3**

Module-1: Introduction to Power System Stability problem. Solution of swing equations, the equal area criterion for stability studies, Power System Operation and Control. Stability Problems faced by modern Power Systems. Impact on Power System Operation and Control.

Module-2: Analysis and Modelling of Dynamical Systems. Concept of Equilibria, Small and Large Disturbance Stability. Example: Single Machine Infinite Bus System. Modal Analysis of Linear Systems. Analysis using Numerical Integration Techniques. Issues in Modeling: Slow and Fast Transients, Stiff Systems.

Modelling of Synchronous Machines. Physical Characteristics. Rotor Position Dependent model. D-Q Transformation. Model with Standard Parameters. Steady State Analysis of Synchronous Machine. Short Circuit Transient Analysis of a Synchronous Machine. Synchronous Machine Connected to Infinite Bus.

Module-3: Modelling of Excitation and Prime Mover Systems, Transmission Lines and Loads. Physical Characteristics and Models. Control system components. Excitation System Controllers. Dynamic modelling of steam turbine, hydro turbine and governor, Prime Mover Control Systems. Transmission Line Physical Characteristics. Transmission Line Modeling. Load Models - induction machine model. Load modelling for stability studies. Other Subsystems - HVDC, protection systems.

Module-4: Stability Issues in Interconnected Power Systems. Small signal stability of a Single Machine Infinite Bus System. Multi-machine Systems. Stability of Relative Motion. Frequency Stability: Centre of Inertia Motion. Concept of Load Sharing: Governors. Single Machine Load Bus System: Voltage Stability. Torsional Oscillations.

Module-5: Power System Stability Analysis Tools. Direct method of transient stability analysis. Transient Stability Program. Small Signal Analysis Program. EMTP Programs. Real-Time Simulators.

Module-6: Enhancement of Power System Stability. Methods of improving stability, Planning Measures. Stabilizing Controllers (Power System Stabilizers). Operational Measures- Preventive Control. Emergency Control.

Reference Books:

1. Power System Dynamics, Stability & Control, K. R. Padiyar, 2nd Edition, B.S. Publications, Hyderabad, 2002.
2. Power System Stability and Control, P. Kundur, McGraw Hill Inc, New York, 1995.
3. Power System Dynamics & Stability, P. Sauer & M. A. Pai, Prentice Hall, 1997.

Course Outcomes: At the end of this course, students will be able to:

1. analyze Key Issues in Power System Stability problem and Stability Problems faced by modern Power Systems
2. analyze and Model of Dynamical Systems using Numerical Integration Techniques.
3. describe Modeling of Excitation and Prime Mover Systems, Transmission Lines and Loads, steam turbine, hydro turbine and governor, Prime Mover Control Systems and Other Subsystems - HVDC, protection systems.
4. understand and use Power System Stability Analysis Tools, Direct method of transient stability analysis, Transient Stability Program, Small Signal Analysis Program, EMTP Programs and Real-Time Simulators.

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	Power System Optimization	L	T	P	C
EE 5212	**M. Tech. (PESE), Second Semester (core)**	**3**	**0**	**0**	**3**

Pre-requisites: Knowledge of Electric Power Systems & Electrical Machines

Module-1: Introduction to optimization problems, Classification of optimization techniques, Traditional and non-traditional optimization techniques, Constrained optimization, linear and non-linear optimization problems in power systems

Module-2: Solution ofoptimization problems with traditional method (Steepest descent and Newton's method), Solution ofoptimization problems with non-traditional method (GA and PSO algorithm).

Module-3: Economic load dispatch (ELD) of thermal power plant, Formulation of optimization problem considering loss and without considering loss, Solution of ELD problem with optimization techniques, Emission economic dispatch, Effect of valve point in ELD problem.

Module-4: Unit commitment and maintenance scheduling of thermal power plants, formulation of optimization problem and solution, Formulation of optimal power flow and its solution

Module-5: Reactive power optimization, Planning of capacitor bank in distribution system- problem formulation and solution.

Text and Reference Books:

1. Power Generation, Operation, and Control, 2nd. ed., A.J. Wood and B.F. Wollenberg, John Wiley & Sons.
2. Economic Operation of Power Systems, L.K. Kirchamayer, John Wiley & Sons.
3. Power System Optimization, D.Kothari, J. S. Dhillon, Prentice Hall India.
4. Engineering optimization- Theory and Practice, Singiresu S. Rao, John Wiley & Sons.

Course Outcomes: At the end of this course, students will be able to:

1. able to classify various power system optimization problems.
2. able to formulate various nonlinear power system optimization problems
3. able to apply suitable computational techniques.
4. Able to analyze the computational issues for efficient operation and control of power system.

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		L	T	P	C
	Modelling and Control of Sustainable Energy System				
EE 5213	**M. Tech. (PESE), Second Semester (core)**	**3**	**0**	**0**	**3**

Module-1: Introduction to renewable energy technologies, overview of micro grids and distributed generation.
Module-2: Modeling of Wind energy conversion systems, Solar PV based systems, Fuel cell and Aqua-electrolyser, Battery and Flywheel based storage system, and Hybrid power system.
Module-3: Power Electronics for Interfacing distributed generation system.
Module-4: Control Strategies and Grid connection interface issues for Grid-Connected and Standalone Sustainable Energy System.
Module-5: Emerging Technologies for distributed generation system integration

Texts and reference materials:

1. N. Jenkins, J. B. Ekanayake, G. Strbac "Distributed Generation", 1st, IET London, 2010
2. S. Chowdhury, S.P. Chowdhury, P. Crossley "Microgrids and Active Distribution Networks", 1st Edition, IET London, 2009
3. Olimpo Anaya-Lara, Nick Jenkins, Janaka Ekanayake, Phill Cartwright, Michael Hughes "Wind Energy Generation: Modelling and Control", 1st Edition, Wiley,2009
4. Munteanu, A. I. Bratcu, N.-A. Cutululis, E. Ceanga "Optimal Control of Wind Energy Systems", 1st Edition, Springer, 2008
5. Thomas Ackermann, Wind Power in Power Systems, John Wiley & Sons ltd., 2005

Course Outcomes: At the end of this course, students will be able to:

1. explain the fundamental concepts concept of distributed generation and microgrids.
2. competency in the development of dynamic model of sustainable energy system.
3. explain the application of Power Electronics for Interfacing distributed generation system.
4. develop Control Strategies for Grid-Connected and Standalone Sustainable Energy System.
5. analyze grid connection interface issues for Grid-Connected and Standalone Sustainable Energy System.
6. update knowledge on Emerging Technologies for distributed generation system integration

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EE 5214	Energy laboratory M. Tech. (PESE), Second Semester	L T P C 0 0 3 2

Topics (Modules/ Sub modules)

1. To determine I-V & P-V characteristics of PV module by varying radiation and temperature.
2. To determine I-V & P-V characteristics of series and parallel combination of PV modules.
3. To show the effect of variation of tilt angle on PV module power.
4. To demonstrate the effect of shading on module output power.
5. To determine the working of diode as bypass diode and blocking diode.
6. Workout power flow calculations of stand- alone PV system of DC load with battery.
7. Workout power flow calculations of stand- alone PV system of AC load with battery.
8. Recording of bright sunshine hours using Campbell-Stokes recorder.
9. To measure the solar radiation using Thermoelectric pyranometer in different global sunshine conditions.
10. Synchronization of grid tied inverter, observation of current waveform and calculations for distortion and power factor of grid tied inverter.
11. Evaluation of the active, reactive power and net energy flow between grid tied inverter, artificial grid & load.
12. Analysis and characterization of wind standalone system.
13. Evaluation of cut-in speed and cut-off speed.
14. I-V characteristics of wind turbine at different wind speed.
15. P, V and f measurement of output of wind generator.
16. Impact of load and wind speed on power output and its quality.

Course Outcome: Upon completion of the course, the students will be able to:

1. understand the working of solar PV and wind energy technology to generate electricity.
2. measure solar radiation, sunshine hours, and do technical analysis of photovoltaic system.
3. conduct experiments related to wind standalone as well as hybrid wind solar system, do technical analysis to study their characteristics.
4. apply the concept to end use applications.

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EE 5215	**SEMINAR II**	**L**	**T**	**P**	**C**
	M. Tech. (PESE), Second Semester	**0**	**0**	**2**	**1**

Course Outcome of Seminar:

At the end of seminar course, students will be able to:

(1) Prepare good slides and present a particular topic effectively.
(2) Develop team spirit and leadership qualities through group activities.
(3) Develop confidence for self-learning and overcome the fear of public presentations.
(4) Update knowledge on contemporary issues, prepare technical report and do presentations on these issues.
(5) Learn technical editing software Latex and write technical report using LaTeX.

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EE 5241	DC and AC power converter M. Tech. (PESE), Second Semester (Elective III & IV)	L	T	P	C
		3	0	0	3

Topics Covered:
Review of power switching devices: Thysristors, GTO, MOSFET, BJT, IGBT and MCT, Trigger techniques, protection circuits

AC-DC Converters:
Module-1: Analysis of line commutated phase-controlled AC-DC converters (one/ two/ four quadrant) configurations (1-phase and 3-phase), Power factor of the phase-controlled converters, Problems of Power Factor in line commutated rectifiers

Module-2: Power factor improvement and harmonic control techniques: Analysis of P – Q diagrams of 1-phase fully controlled and half-controlled converters; methods employing line commutation: use of controlled fly-wheeling, asymmetrical control, sequence control and simultaneous control with controlled fly-wheeling; methods employing forced commutation or self-commutation switches: extinction angle control, symmetrical PWM (single and equal pulse width modulation), selective harmonic elimination technique, sinusoidal PWM, sequence control with forced commutation; Unity Power Factor Converters (single-phase and three-phase): working principles of single-phase boost rectifier (CCM and DCM operations), voltage doubler PWM rectifier, single-phase PWM bridge converter (rectification and regeneration modes), Applications

Module-3: Basic topologies of 3-phase PWM converters, operating principle and analysis of voltage-source current-controlled PWM converter and voltage-source voltage-controlled PWM converter (as rectifier and inverter modes of operations at UPF and at different load conditions, as capacitor and inductor operation at ZPF), New technologies and applications of PWM rectifiers: Universal Power Line Conditioner (UPLC) using line-side PWM converter as Static VAR compensator, Active harmonic filter and Negative sequence compensator combine together; high performance and high reliable four-quadrant variable motor drive system, variable-speed constant frequency wind generating system, Asynchronous frequency link system using double-sided/ back-to-back PWM converter system

DC-DC Converters:
Module-4: Non-isolated DC-DC converters: CCM analysis of step-down (Buck) converter, step-up (Boost) converter and Buck-Boost converter (considering ideal switch, diode and passive components); Effect of non-idealities or parasitics of practical devices and components on performance parameters of converters like forward voltage gain, reverse current gain, efficiency, inductor current ripple and capacitor (output) voltage ripple. DCM analysis of ideal step-down (Buck) converter, step-up (Boost) converter and Buck-Boost converter with concept of critical conduction parameter in each case.

Module-5: Isolated (transformer version) DC-DC converters: Working principle and analysis of forward converter (basic and magnetizing lossless topologies) and effect of parasitics of practical devices and components on its efficiency and voltage gain etc., push-pull converter, half-bridge converter, full-bridge converter fly-back converter, cuk converter.

Module-6: Dynamic model of DC-DC converters: Averaged state-space model (large-signal, steady-state and small-signal) of buck, boost and buck-boost converters, deducing necessary T.F model from averaged state-space models

Reference Books:

1. Power Electronics Handbook Devices, Circuits, & Applications, Muhammad H. Rashid, Academic Press(An imprint of Elsevier).
2. Power Electronics: Converters, Applications and Design, Ned Mohan, Tore M. Undeland and William P. Robbins, John Wiley & Sons, Inc.
3. Thyristorised Power Controllers, G K Dubey, S R Doradla, A Joshi and R M K Sinha, New Age International.
4. Modern Power Electronics and AC Drives, Bimal K. Bose, Pearson Education.
5. Pulse-width Modulated DC–DC Power Converters, Marian K. Kazimierczuk, Pearson Education.

Course Outcomes: At the end of this course, students are able to:

1. understand the details of various power semiconductor switches
2. analyse various AC-DC converters with power factor improvement and harmonic control techniques and their applications
3. analyse various non-isolated and isolated DC-DC converters under continuous and discontinuous modes of operation
4. develop dynamic model of DC-DC converters for its control applications.

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EE 5242	Intelligent algorithms for electric system	L	T	P	C
	M. Tech. (PESE), Second Semester (Elective III & IV)	3	0	0	3

Topics:

Introduction to Artificial Neural Networks (ANNs), multilayer feedforward networks, backpropagation training algorithm, radial basis function and recurrent networks. ANN based algorithms for load flow analysis, economic load dispatch, load forecasting, transient stability, and power system stabilizers. Introduction to genetic algorithms, evolutionary programming.

References:

1. Power Generation, Operation and Control, Allen J. Wood and Bruce F. Wollengerg, Wiley.
2. Power System Analysis, Hadi Saadat, Tata McGraw Hill.
3. Power System Optimization, D.Kothari, J. S. Dhillon, PHI Publication.
4. Genetic Algorithms in Search, Optimization, and Machine Learning, D. E. Goldberg, Addison-Wesley.
5. Neural Networks A Comprehensive Foundation, S. Haykin, Prentice Hall.
6. Neural Networks A Classroom Approach, Satish Kumar, Tata McGraw Hill.

Course Outcome: At the end of this course, students will be able to:

1. define the basics of Intelligent Algorithms (IA).
2. apply suitable IA in solving power system problems.
3. justify the usefulness of IA to solve modern power system problems.

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EE 5243	Distribution automation	L	T	P	C
	M. Tech. (PESE), Second Semester (Elective III & IV)	3	0	0	3

Topic covered

Introduction to Distribution Automation, Configuration of distribution system. Nature of load and load forecasting, Layout of substations and feeders, Design considerations, Distribution system load flow, Optimum siting and sizing of substations, Optimum capacitor placement. Distribution system monitoring and control, SCADA, Remote metering and load control strategies, optimum feeder switching for loss minimization and load control, Distribution system restoration, Distribution system protection and switchgear, power quality issues.

Reference book(s):

1. James A. Momoh.," Electric Power Distribution, Automation, Protection, And Control", CRC Press, 2010

Course Outcomes: At the end of this course, students will be able to:

1. Illustrate the necessity of distribution automation
2. Identify the nature of loads in distribution systems
3. Design the optimum sizing of capacitor in distribution systems
4. Describe the necessity of monitoring and control of Distribution system
5. Summarize the monitoring and control of distribution system.

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EE 5244	Restructured electricity markets M. Tech. (PESE), Second Semester (Elective III & IV)	L	T	P	C
		3	0	0	3

Module-1: Overview of Key Issues In Electric Utilities Restructuring, Introduction, Restructured models, POOLCO Model, Bilateral Contract Model, Hybrid Model, Independent System Operator (ISO), Power Exchange(PX), Market operation, Market Power, Day ahead market operation, Hour ahead market operation, Elastic operation, Inelastic operation, Transmission pricing, Contract path method, MW-mile method, Congestion pricing, OASIS.

Module-2: Congestion management, Introduction, Methods of Congestion management, Market Based Approach, Non-Market Based Approach, Zonal Congestion management, Inter Zonal Congestion Management, Intra Zonal Congestion Management, Available transfer Capability (ATC), Total Transfer Capability(TTC), Power Transfer Distribution factor(PTDF), Line outage Distribution factor(LODF), Price Area Congestion Management.

Module-3: Price of Transmission & Loss allocation, Introduction, Rolled-in pricing, Postage stamp method, MW-Mile Method, Proportionate Sharing Based Method, Graph Theory based Sharing, Equivalent bilateral exchange method, Z bus allocation Method, Marginal pricing based method, Composite pricing based allocation, Transmission loss allocation, Proportional Distributing, Pro-rata based loss allocation, Increment-loss allocation, Proportionate sharing allocation

Module-4: Electric Utility Market, California Market, New York market, PJM Interconnection, ERCOT ISO, New England ISO, MID WEST ISO, OASIS: Open Access Same-Time Information System, Structure of OASIS, Implementation of OASIS Phases, Implementation of OASIS phases. Posting of Information, Transfer Capability on OASIS, Transmission Services, Methodologies to calculate ATC, Experiences with OASIS in some restructuring models,

Module-5: Hedging Tools for Managing Risks in Electricity Markets, Sources of Electricity Markets Risks, Value at Risks, Bidding Strategies, Methods of strategies, Deterministic method, stochastic method

Reference Books:

1. Applied Mathematics for Restructured Electric Power Systems: Optimization, Control, and Computational Intelligence, Joe H. Chow, Felix F. Wu, James A. Momoh (auth.), Joe H. Chow, Felix F. Wu, James Momoh, Springe.
2. Restructured Electric Power Systems: Analysis of Electricity Markets with Equilibrium Models, Xiao-Ping Zhang, Wiley-IEEE Press.
3. Restructured Electrical Power Systems, Muwaffaq Alomoush, Mohammad Shahidehpour, M. Dekker.
4. Power System Restructuring and Deregulation_ Trading, Performance and Information Technology, Loi Lei Lai, Wiley (2001).

Course Outcomes: At the end of this course, students will be able to:

1) analyze Key Issues In Electric Utilities Restructuring for different Restructured models,
2) implement Methods of Congestion management, Market Based Approach, Non-Market Based Approach
3) describe different Electric Utility Market and Open Access Same-Time Information System.
4) understand Hedging Tools for Managing Risks in Electricity Markets and design different Bidding Strategies for electricity markets.

EE 5245	**Quantitative methods for energy management and planning**	**L T P C**
	M. Tech. (PESE), Second Semester (Elective III & IV)	**3 0 0 3**

Topics Covered:

Module-1: A review of probabilities concepts: Axioms of probability, Conditional probability, Baye's theorem, Permutation, combinations, Binomial coefficients.

Module-2: Introduction to operation research: The nature and significance of operation research, Features of operation research approach, Applications and scope of operation research, Sequencing, Queuingtheory, Networks, PERT and CPM

Module-3: Linear programming: Application and model formulation, Graphical model, Simplex method, Duality in linear programming.

Module-4: Integer programming problem: Cutting method, Search method, Gomory's fractional cut algorithm.

Module-5: Decision theory and decision trees: Decision making under uncertainty, Decision making under risk, Transportation problems, Sequencing.

Reference Books:

1. Operations Research, An Introduction, HA Taha, Prentice Hall.
2. Quantitative Techniques in Management, ND Vohra, Tata McGraw Hill.
3. Management of Energy Environment Systems, W.K.Foell, John Wiley and Sons.

Course Outcomes: At the end of this course, students will be able to:

1. analyse the concepts of Operations management
2. execute a comprehensive plan for Energy conservation
3. describe the problem formulation of operation research
4. design the framework for decision making process

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EE 5246	Energy conservation and management M. Tech. (PESE), Second Semester (Elective III & IV)	L	T	P	C
		3	0	0	3

Module-1: ENERGY SCENARIO: Commercial and Non-commercial energy, primary energy resources, commercial energy production, final energy consumption, energy needs of growing economy, long term energy scenario, energy pricing, energy sector reforms, energy and environment, energy security, energy conservation and its importance, restructuring of the energy supply sector, energy strategy for the future, air pollution, climate change. Energy Conservation Act-2001 and its features.

Module-2: BASICS OF ENERGY AND ITS VARIOUS FORMS: Electricity tariff, load management and maximum demand control, power factor improvement, selection & location of capacitors, Thermal Basics-fuels, thermal energy contents of fuel, temperature & pressure, heat capacity, sensible and latent heat, evaporation, condensation, steam, moist air and humidity & heat transfer, units and conversion.

Module-3: ENERGY MANAGEMENT & AUDIT: Definition, energy audit, need, types of energy audit. Energy management (audit)approach understanding energy costs, bench marking, energy performance, matching energy use to requirement, maximizing system efficiencies, optimizing the input energy requirements, fuel & energy substitution, energy audit instruments.

Module-4: ENERGY EFFICIENCY IN ELECTRICAL SYSTEMS: Electrical system: Electricity billing, electrical load management and maximum demand control, power factor improvement and its benefit, selection and location of capacitors, performance assessment of PF capacitors, distribution and 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.

Module-5: ENERGY EFFICIENCY IN INDUSTRIAL SYSTEMS: Pumps and Pumping System: Types, performance evaluation, efficient system operation, flow control strategies and energy conservation opportunities. Cooling Tower: Types and performance evaluation, efficient system operation, flow control strategies and energy saving opportunities, assessment of cooling towers.

Module-6: ENERGY EFFICIENT TECHNOLOGIES IN ELECTRICAL SYSTEMS: Maximum demand controllers, automatic power factor controllers, energy efficient motors, soft starters with energy saver, variable speed drives, energy efficient transformers, electronic ballast, occupancy sensors, energy efficient lighting controls, energy saving potential of each technology.

TEXT BOOKS:

1. "Optimizing Energy Efficiencies in Industry", G. G. Rajan, Tata McGraw Hill.
2. Energy Auditing and Conservation; Methods, Measurements, Management and Case Study"", Hemisphere Publishers.
3. "Industrial Energy Conservation", Charles M. Gottschalk, John Wiley and Sons.

Reference Books:

1. “Utilization of Electrical Energy and Conservation”, S. C. Tripathy, McGraw Hill, 1991.
2. “Success stories of Energy Conservation by BEE”, New Delhi (www.bee-india.org).
3. “Guide books for National Certification Examination for Energy Manager / Energy Auditors Book-1”, General Aspects (available online)
4. “Guide books for National Certification Examination for Energy Manager / Energy Auditors Book-3”, Electrical Utilities (available online).

Course Outcomes: At the end of this course, students will be able to:

1. understand the concept of energy scenario
2. understand the theory of tariff and thermal management in electrical system.
3. understand the basic concepts of energy audit& management
4. analyze energy saving opportunities.

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EE 5247	Power system reliability	L	T	P	C
	M. Tech. (PESE), Second Semester (Elective III & IV)	3	0	0	3

Topics to be covered:

Module-1: Basic Reliability Concepts, series and parallel system models, Markov processes and their applications, power system reliability, concept of adequacy and security, reliability cost and reliability worth.

Module-2: Generating system reliability Analysis, Generation system model, loss of load indices, Capacity expansion analysis, Scheduled outages, load forecast uncertainty, loss of energy indices, Frequency and Duration methods, interconnected system- basic concepts, evaluation techniques. Operating reserve calculations, spinning capacity evaluation, unit commitment risk.

Module-3: Reliability of composite generation and transmission Systems, Radial configuration, Conditional probability approach, Network configurations, State selection, System and load point Indices.

Module-4: Distribution systems reliability evaluation techniques, customer-oriented indices, load and energy-oriented indices, application to radial systems, Effect of lateral distribution protection, Effect of disconnects, Effect of protection failures, Effect of transferring loads, parallel and meshed networks' reliability evaluation techniques.

Module-5: Basic concepts of substation and switching station reliability, reliability analysis of protection system for high voltage transmission lines.

Reference Books:

1. Reliability evaluation of Power Systems, R. Billinton , R. N. Allan, Springer.
2. Reliability Modelling in Electric Power Systems, J. Endrenyi, John Wiley and Sons.
3. Reliability evaluation of Engineering Systems, R. Billinton , R. N. Allan, Springer.

Course Outcomes: At the end of this course, students will be able to:

1. understand, analyze and apply the basic concept of power system reliability.
2. apply the probabilistic methods for evaluating the reliability of power generation system as well as composite generation and transmission systems.
3. analyze and evaluate power distribution system reliability using various reliability indices.
4. analyze and determine the reliability of substation and that of protection system for high voltage transmission lines.

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EE 5248	Parameter estimation and system identification M. Tech. (PESE), Second Semester (Elective III & IV)	L	T	P	C
		3	0	0	3

Topics Covered:

Module-1: Introduction: Dynamic system, Models, Problem, System identification procedure Background: Random Variables and Stochastic Processes, Signals and Systems, Model Parameterization and Prediction

Module-2: Part 1: Systems and Models

Different Models of Systems: LTI System: - Family of Discrete Transfer function Models- State Space models- Distributed Parameter Model. Models for Time varying and Nonlinear System: Linear Time varying models- Non-linear State space models- Non-linear Black Box and grey-box Models

Module-3: Part 2: Methods

Nonparametric Identification: - Impulse and Step Response, Correlation Methods, Spectral Analysis

Parameter Estimation Methods: - General Principles- Minimizing Prediction errors- Linear Regression and the Least Square method- Statistical Frame work for Parameter Estimation and the Maximum Likely hood method- Instrument Variable method – Recursive and Weighted Least square method, Convergence and Consistency, Asymptotic Distribution of Parameter Estimates

Module-4: Algorithms: Computing the Estimates, Recursive Estimation Kalman Filter Interpretation

References books:

1. Lennart Ljung, System Identification Theory for the user, Prentice Hall Information and system sciences Series, NJ, 1999.
2. K.J Keesman,*System Identification: An Introduction*. Springer Science & Business Media.
3. P. Deshponde and Ash, Computer Controlled System, ISA Press, USA
4. Richard H. Middleton and Graham C. Goodwin, Digital Control and Estimation A Unified Approach, Prentice Hall NJ, 1990
5. Dale E. Seborg, Thomas F. Edgar, Duncan A. Mellichamp, Process Dynamics and Control,Willey India, 2006. 5. Astrom .K. J, Bjorn Wittenmark, Adaptive Control, Second Edition, Prentice Hall of India, New Delhi, 1994.

MOOC on this course are available at:

1. System Identification and Parameter Estimation, Dr. Erwin de Vlugt: https://ocw.tudelft.nl/course-lectures/introduction-system-identification-parameter-estimation/
2. System Identification, Prof. Munther Dahleh: https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-435-system-identification-spring-2005/
3. Introduction to the course System Identification and Parameter Estimation**:** https://www.youtube.com/watch?v=d8dXoJ9MoDs
4. Introduction to System Identification**:** https://www.youtube.com/watch?v=u7hJ1aF-JrU

Course Outcomes: By the end of this course, the student will be able to:

1. understand the basics of system Modelling and identification
2. formulate the models for linear and nonlinear systems.
3. apply practically the concepts of Modelling and identification to simple engineering problems.
4. analyse the various methods of the nonparametric and parameter estimation with its algorithms.

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EE 5249	Power system transients	L	T	P	C
	M. Tech. (PESE), Second Semester (Elective III & IV)	3	0	0	3

Topics Covered:

Module-1: Source of transients, Various types of power systems transients, Effect of transients on power systems, importance of study of transients in planning.

Module-2: Switching Transients: RL circuit with sine wave drive, Double frequency transients, Observations in RLC circuit and basic transforms of the RLC circuit, Resistance switching, Equivalent circuit for the resistance switching problems, Equivalent circuit for interrupting the resistor current.

Module-3: Load switching: Waveforms for transient voltage across the load switch, normal and abnormal switching transients, Current suppression, Current chopping, Effective equivalent circuit, Capacitance switching, Effect of source regulation, Capacitance switching with a restrike, with multiple restrikes, Ferro resonance.

Module-4: Lightning Transients - Lightning phenomenon, Charge formation in the clouds, Rate of charging of thunder clouds, Mechanisms of lighting strokes, Characteristics of lightning strokes, Factors contributing to good line design, Protection afforded by ground wires, Tower footing resistance, Interaction between lightning and power system.

Module-5: Travelling Waves: Travelling wave concept-Velocity of Travelling waves and Characteristic Impedance, Energy Contents of Travelling Waves, Attenuation and Distortion of Electromagnetic Waves, telegraph equations-lossless line, distortion less line; Standing waves and natural frequencies, Reflection and Refraction of Travelling Waves, Reflection of Travelling Waves against Transformer-and-Generator-windings, the Origin Transient Recovery voltages, the lattice diagram.

Module-6: Transients in Integrated Power System: The short line and kilometric fault, Distribution of voltage in a power system, Line dropping and load rejection, Voltage transients on closing and reclosing lines, over voltage induced by faults, Switching surges on integrated system, EMTP for transient computation

Module-7: Power System Transient Recovery Voltages: Characteristics of the Transient Voltage- Short-circuit test duties based on IEC 60056 (1987),ANSI/IEEE Standards, the Harmonization between IEC and ANSI/IEEE Standards with respect to Short-circuit Test duties, Transient recovery voltage for Different types of faults.

Reference Books:

1. Electrical Transients in Power Systems, Allan Greenwood, Wiley Interscience.
2. Power System Transients: A Statistical Approach, C.S Indulkar, D.P. Kothari, K. Ramalingam, PHI.
3. Power System Transients: Theory and Applications, Akihiro Ametani, Naoto Nagaoka, Yoshihiro Baba, Teruo Ohno, CRC Press 2013.
4. Transients in Power Systems, Lou van der Sluis, John Wiley & Sons.

Course Outcomes: At the end of this course, students will be able to:

1) analyse the electrical transients in power systems.
2) describe traveling waves on transmission line and transients
3) describe the issues related to insulation coordination, grounding and limiting of surge effects.

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EE 5250	Electrical Networks and Pricing	L	T	P	C
	M. Tech. (PESE), Second Semester (Elective III & IV)	3	0	0	3

Pre-requisites: Power Systems

Module-1: Restructuring: Introduction to restructuring of power industry.

Module-2: Fundamentals of economics: Competitive market, supply and demand curve, elasticity and inelasticity, market equilibrium, Pareto efficiency, short run and long run cost.

Module-3: Philosophy of market models: Introduction, various energy markets, trading arrangements.

Module-4: Transmission congestion management, Locational marginal prices (LMP) and financial transmission rights (FTR).

Module-5: Pricing of transmission network usage and loss allocation: Introduction to transmission pricing, principles of transmission pricing, classification of transmission pricing, rolled-in transmission pricing methods, Marginal transmission pricing paradigms, Composite pricing paradigms, Merits and demerits of different paradigms, Debated issues in transmission pricing, Classification of loss allocation methods, comparison between various methods.

Module-6: Introduction to optimal bidding by generator companies, optimal bidding methods.

Reference Books:

1. Fundamentals of power system economics, D. Kirschen& G. Strbac, John Wiley & Son's Ltd
2. Making competition work in electricity, S.Hunt & K.Bhattacharya, John Wiley & Son's ltd.
3. Operation of restructured power systems, J.E.Daadler, M.H.J.Bollen, Kluwer academic publishers.
4. Effective power marketing, Clark W Gellings, Pennwell publishers.
5. Maintenance scheduling in a restructured power system, Shahidehpour M &Marwali, Kluwer academic publishers

Course Outcomes: At the end of this course, students are expected to learn the following:

1 Able to state the fundamentals of competitive market.

2 Able to describe the necessity of restructuring the electricity market.

3 Able to identify the role of various entities in energy market.

4 Able to demonstrate the energy bidding strategies by the market participants

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EE 6298	**Project Phase -I**	**L**	**T**	**P**	**C**
	M. Tech. (PESE), Third Semester	**-**	**-**	**-**	**06**

Course Outcomes: At the end of this project phase I, students will be able to:

1. Identify the complex engineering problem and find possible solutions.
2. Apply the technical, software, and hardware knowledge to carry out their project work.
3. Create technical report of the project work.
4. Communicate the findings technically in written and oral forms with engineering community at large.

EE 6299	**Project Phase -II**	**L**	**T**	**P**	**C**
	M. Tech. (PESE), Fourth Semester	**-**	**-**	**-**	**08**

Course Outcomes: At the end of this project phase I, students will be able to:

1. Identify the complex engineering problem and find possible solutions.
2. Apply the technical, software, and hardware knowledge to carry out their project work.
3. Create technical report of the project work.
4. Communicate the findings technically in written and oral forms with engineering community at large.