August, 2019

M.TECH - RENEWABLE ENERGY TECHNOLOGY (2019)

Renewable energy being the most important application area of engineering and technology in the twenty first century, this graduate programme is designed for quality learning in that sector. RE sector needs manpower with design and engineering skills in RE systems and components – this programme targets to impart these. The curriculum has an emphasis on solar and wind energy systems, in tune with the Indian national missions on these. Job avenues targeted are RE equipment manufacturers, farm developers and system operators; also, the qualified human resource requirement in RE teaching and research is potentially high.

The learning is guided through two parallel streams of electrical and mechanical disciplines. Core courses and electives of specialization are offered by faculty from various departments like Electrical and Electronics, Mechanical, Aerospace, Business Management, Science etc.

A Renewable Energy laboratory developed through assistance from C-WET, MNRE and DST, Government of India, equipped with hard and soft experiment systems and real field data collection systems, provides active training support to the programme. Collaborations with global academic and industrial establishments too help in imparting quality learning in this programme.

Curriculum

First Semester

Course Code	Type	Course Title	LTP	Cr
19MA607	FC	Probability Statistics and Random Process	3-1-0	4
19RE601	FC	Electronic Instrumentation Systems	3-0-2	4
19RE611	SC	Solar Energy	3-0-0	3
19RE612	SC	Bio and Hydro Energy Sources	3-0-0	3
19RE613	SC	Soft Computing	2-0-2	3
	E	Elective I	3-0-0	3
19RE621	SC	Renewable Energy Laboratory I	0-1-2	2
19HU601	HU	Amrita Values Program*		P/F
19HU602	HU	Career Competency I*		P/F
Total for Sem I				22

*Non-Credit Course

Second Semester

Course Code	Type	Course Title	L T P	Cr
19RE602	FC	Energy Economics and Renewable Energy Policy	3-0-0	3
19RE614	SC	Energy Management	3-0-0	3
19RE615	SC	Wind Energy	3-0-0	3
	E	Elective II / Live-in Labs**	3-0-0	3
	E	Elective III	3-0-0	3
	E	Elective IV	3-0-0	3
19RM600	SC	Research Methodology	2-0-0	2
19RE622	SC	Renewable Energy Laboratory II	0-0-4	2
19HU603	HU	Career Competency II	0-0-2	1
Total for Sem II				23

Third Semester

Course Code	Type	Course Title	L T P	Cr
19RE798	P	Dissertation		8
Total for Sem III				8

Fourth Semester

Course Code	Type	Course Title	L T P	Cr
19RE799	P	Dissertation		12
Total for Sem IV				12
Total for the programme				65

List of Courses

Foundation Core

Course Code	Course Title	LTP	Cr
19MA607	Probability Statistics and Random Process	3-1-0	4
19RE601	Electronic Instrumentation Systems	3-0-2	4
19RE602	Energy Economics and Renewable Energy Policy	3-0-0	3

Subject Core

Course Code	Course Title	LTP	Cr
19RE611	Solar Energy	3-0-0	3
19RE612	Bio and Hydro Energy Sources	3-0-0	3
19RE613	Soft Computing	2-0-2	3
19RE614	Energy Management	3-0-0	3
19RE615	Wind Energy	3-0-0	3
19RM600	Research Methodology	2-0-0	2
19RE621	Renewable Energy Laboratory I	0-1-2	2
19RE622	Renewable Energy Laboratory II	0-0-4	2

Electives

Course Code	Course Title	LTP	Cr
19PE718	Power System Modeling	3-0-0	3
19RE701	Solar Thermal Engineering	3-0-0	3
19PE705	Electrical Machine Analysis Using Finite Element Analysis	3-0-0	3
19PE709	Programmable Logic Controllers	3-0-0	3
19PE716	Power System Operation and Control	2-0-2	3
19RE702	Power Electronics for Energy Systems	3-0-0	3
19RE703	Flexible AC and High Voltage DC Transmission Systems	3-0-0	3
19RE704	Aerodynamics and Wind Turbines	3-0-0	3
19RE705	Wind Electric Generators	3-0-0	3
19RE706	Applied Computational Fluid Dynamics	3-0-0	3
19RE707	Energy Storage Systems	3-0-0	3
19RE708	Smart Grid	2-1-0	3
19RE709	Electrochemical Energy Systems	3-0-0	3
19RE710	Project Management	3-0-0	3
19RE711	Energy Forecasting and Modeling	3-0-0	3
19RE712	Ocean Energy Conversion	3-0-0	3
19RE713	Computational Optimization Theory – Linear and Non-Linear Methods	3-0-0	3
19RE714	Electric Power Quality	3-0-0	3
19RE715	Distributed Generation	3-0-0	3

Project Work

Course Code	Course Title	L T P	Cr
19RE798	Dissertation		8
19RE799	Dissertation		12

19MA607 PROBABILITY STATISTICS ANDRANDOM PROCESS 3-1-0-4

Course Objectives:

- Understand and apply the concepts of Random variables, Regression Estimation, Random Process and special distributions

Course Outcome (CO)

CO.1	Understanding of the concepts of Random variables of one and two dimensions, the connected probability distributions, mean, variance and their real time applications
CO.2	Knowledge of the significance of the theory of estimation, Test of Hypothesis, Interval Estimation, etc.
CO.3	Knowledge of the linear relationship between two random variables and the relationship between them using the linear Regression Estimation
CO.4	Knowledge of the basic concepts of the Random Process and various special distributions
CO.5	Understanding of the concepts of spectral density and ergodicity of random process
CO.6	Knowledge of the Markov process and chain and its significance in practical problems.

Review: Sample Space and Events, Interpretations and Axioms of Probability, Addition rules, Conditional Probability, Multiplication and Total Probability rules, Independence, Bayes theorem.

Discrete Random variables, Probability Distributions and Probability mass functions, Cumulative Distribution functions, mathematical expectation and variance, Standard distributions - discrete distributions - binomial, Poisson and geometric distributions - continuous distributions - uniform, exponential, Normal distributions - Chebyshev's theorem. Joint, marginal and conditional probability distributions for discrete and continuous cases, independence, expectation of two dimensional random variables, conditional mean and variance, Simple linear Regression, Properties of least square estimators, least squares method for estimation of regression coefficients, Correlation, properties of correlation coefficient. Point Estimation, Sampling Distributions and Central limit theorem, Method of Maximum likelihood Estimation -Confidence Interval on the mean of a Normal Distribution with Variance known and unknown, - Confidence interval on the variance and ratio of variances. Confidence interval for Population Proportion. Hypothesis Testing, Tests on the Mean of a Normal Distribution with Variance known and unknown - Tests on a Population Proportion - Tests on the variance -Test for Goodness of fit, Contingency table . Charts- BAR chart, Pi-chart central measures for given data, Correlations and regressions, Test of Hypothesis.

Random Processes: General concepts and definitions-Stationarity in random process-autocorrelation and properties-Poisson points, Poisson and Gaussian processes-Spectrum estimation- Ergodicity and mean Ergodic theorem-Power spectral density and properties. Markov processes –Markov Chains – Transition Probability matrix- Classification of states-Limiting Distributions.

TEXT BOOKS / REFERENCES:

1. Douglas C. Montgomery and George C. Runger, "*Applied Statistics and Probability for Engineers*", John Wiley and Sons Inc., 2005.
2. Roy D. Yates, *"Probability and Stochastic Processes A Friendly Introduction for Electrical and Computer Engineers"* Second EditionJohn Wiley and Sons Inc., 2005.
3. Ravichandran, J. "*Probability and Statistics for Engineers*",Wiley India, 2012.

19RE601 ELECTRONIC INSTRUMENTATION SYSTEMS 3-0-2-4

Course Objectives:

- Understand the requirements of measurement and instrumentation
- Learn principles of transducers
- Design signal conditioning circuits
- Design microcontroller based measurement and control circuits
- Familiarize with PLC system and its applications

Course Outcome(CO)

CO.1	Understanding of the basic concepts of measurement and instrumentation systems
CO.2	Understanding of the operation and specifications of Transducers
CO.3	Ability to design the signal conditioning units
CO.4	Ability to apply concepts of microcontroller for measurement and control processes.
CO.5	Familiarity on counters and timers of PLC for control applications

Measuring systems - classification, static and dynamic characteristics, errors, calibration and standards. Mechanical transducers: pressure measurement- diaphragms; torque measurement, strain gauge. Vibration measurement. Anemometers – cup, hot wire, SODAR, LIDAR. Sunshine recorder, pyranometer, pyrheliometer.GIS.

Passive electrical transducers: Resistive, thermal radiation detectors, hotwire resistance, resistive displacement, resistive strain, resistive pressure, linear variable differential transformer.

Active electrical transducers: Thermoelectric-thermocouples, RTD, piezoelectric, Hall Effect, digital displacement, photo electric. Level, flow measurements, SCADA, Smart meters (net metering), Phasor measurement unit, basic measurements/sensing with ADC,CCP modules in PIC microcontrollers.

PLC: architecture, programming, ladder diagram, communications and networking, selection and installation. Communication Technologies: wired, wireless. RF -Zigbee, Bluetooth, WiFi, Ethernet, GSM, GPRS.Data acquisition systems, data loggers.

TEXT BOOKS/ REFERENCES:

1. D.V.S.Murty, "*Transducers and Instrumentation*", Second Edition, Prentice-Hall of India Private Limited, 2008.
2. ArunK.Ghosh, "*Introduction to Measurements and Instrumentation*", Third Edition, PHI Learning Private Limited, 2009.
3. S. K. Singh, "*Computer Aided Process Control*", Prentice-Hall of India Private Limited, 2003.
4. William Stallings, "*Wireless Communications and Networks*", Second Edition, Pearson Education, 2005.

19RE611 SOLAR ENERGY 3-0-0-3

Course Objectives:

- Understand the fundamentals of solar energy conversion and familiarize with solar geometry
- Design PV systems and analyze performance
- Familiarize with solar energy policies and costing.

Course Outcome(CO)

CO.1	Understanding of properties of solar energy resource, PV and ST system operation and component specifications
CO.2	Computation of circuit parameters, solar geometry and cell/array performance parameters
CO.3	Familiarization of PV installations, government policies and costing
CO.4	Design of PV systems for domestic, commercial and industrial applications
CO.5	Analysis of PV systems performance based on performance indices

History of Solar Energy, Properties of Sun Light- Solar Radiation - Solar Radiation– Atmospheric effects - Solar Geometry - Measuring Instruments - Estimation of Solar Radiation.

Solar Thermal Systems: Solar Thermal Collector and its types, Solar-thermal Energy Storage System, Applicationsof Solar Thermal System.

Solar cell physics & characteristics – dark and illuminate junctions,parasitic resistances, Irradiance and temperature effects, STC and NOCT conditions,Maximum power point.

PV cell architecture and fabrication steps, crystalline Si substrates, thin film deposition, amorphous Si, CIGS, CdTe etc., dye sensitized cell.

PV Module and Array –By pass and blocking diodes - Tilt angle and Sun Tracking.Balance of system components and their design – for stand alone and grid connected operation, MPPT Algorithms. Stand Alone PV System, Grid Connected PV System, Hybrid Systems.

Installation of SPV Systems; Cost analysis and pay back calculations; Environmental and safety issues.

TEXT BOOKS/ REFERENCES:

1. Nelson J, "*The Physics of Solar Cell*", Imperial College Press, 2006.
2. Wenham SR, "*Applied Photovoltaic*", Second Edition, Earthscan Publications Ltd, 2007.
3. G.N. Tiwari, "*Solar Energy-Fundamentals, Design, Modeling and Applications*", Narosa Publishers, 2002.
4. F. Kreith and J.F. Kreider, "*Principles of Solar Engineering*", McGraw Hill, 1978.
5. John Twidell and Tony Weir, "*Renewable Energy Resources*", Second Edition, Taylor and Francis, 2005.

19RE612 BIO AND HYDRO ENERGY SOURCES 3-0-0-3

Course Objectives:

- Learn principles of extraction of energy from biomass and water
- Design bio and hydro power conversion systems
- Learn principles of tidal, wave and ocean thermal energy conversion

Course Outcome(CO)

CO.1	Understanding the principles of extraction of energy from biomass and water
CO.2	Familiarity with various biomass conversion processes
CO.3	Design of bio and hydro power generation systems
CO.4	Familiarity with hydro power extraction from oceans

Energy from biomass: sources, classification, conversion into fuels, photosynthesis, C3 and C4 plants on biomass production, physicochemical characteristics; CO2 fixation potential. Biomass resource assessment, biomass productivity study, waste land utilization through energy plantation. Biomass conversion process: biochemical - anaerobic digestion, biogas production mechanism and technology, types of digesters, design of biogas plants; chemical - hydrolysis and hydrogenation, bio-fuels, Biodiesel production, fuel characteristics; thermochemical - pyrolysis, combustion and gasification, gasifiers: updraft, downdraft, fluidized bed, biomass carbonization, natural draft and gasification based biomass stoves, gasification based power generation. Design of power plants.Hydrology, Selection of site, Resource assessment, Classification of Hydropower Plants, Small Hydropower Systems: mini, micro and pico systems, Pumped storage plants, Hydraulic Turbines: classification and operational aspects, elements of turbine, selection and design criteria, Planning of power house, Hydro power from oceans – Wave and Tidal power, Electronic load controller; environmental issues related to hydro projects.

TEXT BOOKS/ REFERENCES:

1. Sorensen B., "*Renewable Energy*", Second Edition, Academic Press, 2000.
2. Ravindranath N. H. and Hall D. O., "*Biomass, Energy and Environment*", Oxford University Press, 1995.
3. Rosillo-Calle F. and Francisco R., "*The Biomass Assessment Handbook: Bioenergy for a SustainableEnvironment*", Earthscan, 2007.
4. Wagner H. and Mathur J, "*Introduction to Hydro Energy Systems: Basics, Technology and Operation*", Springer, 2011.
5. John Twidell and Tony Weir, "Renewable Energy Resources", Second Edition, Taylor and Francis, 2005.
6. M. M. Dandekar and K. N. Sharma, "Water Power Engineering", Vikas Publishing House Pvt. Ltd., Second Edition, 2014.

19RE613 SOFT COMPUTING 2-0-2-3

Course Objectives:

- To learn different soft computing techniques
- To introduce application of evolutionary algorithms to optimization problems
- To learn solution of real time problems using soft computing

Course Outcome(CO)

CO.1	Apply neural networks to pattern classification and regression problems
CO.2	Solve engineering problems with uncertainty using fuzzy logic technique
CO.3	Apply evolutionary algorithms for optimization problems.
CO.4	Apply software tools to solve real time problems by soft computing techniques.

Fuzzy Logic (FL) – Membership Functions – Fuzzifications and Defuzzifications – Fuzzy Relations – TSK Fuzzy Modeling.Neural Networks (NN) – Supervised and Unsupervised Learning – Hopfield – RBF Networks Kohonen Self Organizing Networks – Learning Vector Quantization – Hebbian Learning.

Neuro-fuzzy models- adaptive neuro-fuzzy inference system (ANFIS)- Architecture – Hybrid Learning Algorithm – Learning Methods that Cross-fertilize ANFIS and RBFN - Applications.

Genetic Algorithms– Random Search – Downhill Simplex Search.

Introduction to Support Vector Machines – Classification and Regression – Typical Applications Integrating Various Soft Computing Tools.

TEXT BOOKS/ REFERENCES:

1. Timothy Ross, "*Fuzzy Logic with Engineering Applications*", Second Edition, John Wiley and sons, 2004.
2. Simon Haykin, "*Neural Networks and Learning Machines*", Third Edition, Pearson Education, 2009.
3. K.F. Man, K.S. Tang and S. Kwong, "*Genetic Algorithms: Concepts and Applications*", IEEE Transactions Industrial Electronics, Vol-3,1996.
4. Jan Komorowski, Lech Polkowski and AndrzejSkowron, "*Rough Sets: ATutorial*",http://Folli.Loria.Fr/Cds/1999/Library/Pdf/Skowron.Pdf

19RE621 RENEWABLE ENERGY LABORATORY I 0-1-2-2

Course Objectives:

- Familiarize with the modelling, simulation and field testing of PV system and components
- Use domain specific software and instruments used in the energy sector.

Course Outcome(CO)

CO.1	Hands on experience in PV systems, battery, etc
CO.2	Field testing of PV systems and components
CO.3	Modelling and simulation of PV systems and components
CO.4	Familiarity in use of software like PV Syst and Matlab Simulink
CO.5	Skill is use of instruments like data loggers, irradiance meter, etc.

Laboratory experiments on solar photovoltaic panels and modeling and simulation. Software based studies on grid-connected SPV.

18RE602 ENERGY ECONOMICS AND RENEWABLE ENERGY POLICY 3-0-0-3

Course Objectives:

- Learn basic economics concepts of demand, production and cost
- Compute techno-economic performance indices of energy conversion and end use systems
- Familiarize with global and national energy policies

Course Outcome(CO)

CO.1	Understanding of the basic economics concepts of demand, production and cost
CO.2	Computation of time value of money
CO.3	Assessment of economic performance of industry/business
CO.4	Familiarization of global and national energy policies
CO.5	Techno-economic analysis of energy production/supply systems

Energy economics: Basic concepts, Energy data and energy balance. Energy Accounting framework; Economic theory of demand, production and cost market structure.

Costing: Time value of money – present worth and future worth; Economic performance indices – simple and discounted payback, Levelised cost - calculation of unit cost of power generation, cost-benefit ratio, E/D ratio, net present value, Internal rate of return.

Energy-GDP elasticity; National and regional energypolicies - RE certificate, RE purchase obligation, subsidy and taxation, Renewable Recovery Fund, Energy Exchange- deregulated power market, electricity regulations, Grid Code.

Energy- Environment interactions at different levels; Energy security issues.

TEXT BOOKS/ REFERENCES:

1. Bhattacharyya S. C., "*Energy Economics*", Springer, 2011.
2. Ferdinand E. B., "*Energy Economics: A Modern Introduction*", Kluwer, 2000.
3. Kandpal T. C. and Garg H. P., "*Financial Evaluation of Renewable Energy Technology*", Mac Milan, 2003.
4. Munasinghe M. and Meier P., "Energy Policy Analysis and *Modeling*", Cambridge University Press, 1993.

19RE614 ENERGY MANAGEMENT 3-0-0-3

Course Objectives:

- Estimate energy efficiency in electrical equipment as well as in thermal fuels and combustion systems
- Learn energy conservation opportunities and techniques in domestic, commercial and industrial sectors
- Familiarize with energy audit

Course Outcome(CO)

CO.1	Understanding of issues related to climate change, energy supply security and energy policies
CO.2	Computational knowhow in energy efficiency estimation in electrical appliances and equipment as well as fuels and combustion
CO.3	Knowledge of energy conservation techniques in domestic, commercial and industrial sectors
CO.4	Synthesis of industrial energy subsystem models
CO.5	Analysis of energy audit observations

Historical development of commercial energy supply: Commercial energy in ancient times, Renewable Energy utilization in ancient times, Industrial revolution, Realization of environmental concerns, Developments in Renewable Energy Sector; Concept of Energy Efficiency and Clean Production. Energy Conservation Act 2001 and its features.

Energy conservation on demand side: Efficient Lighting; Energy Efficiency in motors, pumps and fans. Power quality issues related to Energy Efficient Technologies. Energy saving and trading Evaluation of thermal performance – calculation of heat loss – heat gain, estimation of heating & cooling loads, factors that influence thermal performance, waste heat recovery and co-generation, analysis of existing buildings setting up an energy management programme – electricity saving techniques.

Energy Management in Electrical Power Systems: Supply-demand gap on electric power grid: causes and remedial measures. Demand Response; Microgrids and Smart grid.

Energy Management and Audit: Functions and methodologies of preliminary as well as detailed energy audits; Pre-audit, audit and post-audit measures Instruments for energy audit, Energy Service Companies (ESCOs), Energy Conservation Policies and Regulations, Energy Conservation Practice – Case Studies.

TEXT BOOKS/ REFERENCES:

1. Hamies, "*Energy Auditing and Conservation; Methods, Measurements, Management and Case Study*", Hemisphere Publishers, Washington, 1980.

2. C.W. Gellings and J.H. Chamberlin, "*Demand-Side Management Planning*", Fairmount Press, 1993.

3. Wayne C Turner, "*Energy Management Handbook*", The Fairmount Press, 2006.

4. Bureau of Energy Efficiency Study Material for Energy Managers and Auditors Examination: Paper I to IV, www.energymanagertraining.com

5. S. Pabla, "*Electric Power Systems Planning*", Mac Millan India Ltd., 1998.

6. MoncefKrarti, "*Energy Audit of Building Systems: An Engineering Approach*", Second Edition, CRC Press, 08-Nov-2010 // e-book//.

7. Amit K. Tyagi, "*Handbook on Energy Audits and Management*", TERI, 2003.

19RE615 WIND ENERGY3-0-0-3

Course Objectives:

- Learn wind regime modeling and resource assessment
- Learn basic principles and operational features of wind turbines and WTG
- Familiarize with grid connected and off grid applications of wind energy
- Conduct performance analysis of WECS

Course Outcome(CO)

CO.1	Understanding of wind resource, principles of conversion and technologies
CO.2	Modeling of wind regimes and assessment of wind resource
CO.3	Understanding of operation and constraints of wind turbine generators
CO.4	System design for grid connected and off grid applications of wind energy
CO.5	Performance analysis of WECS

Meteorology of wind: Global circulation, Forces influencing wind, Local Wind systems, Wind Speed modeling – Weibull parameters and estimation, Wind Rose.

Wind Turbines: Types, Rotor elements; Horizontal and vertical axis wind turbines, Power in the wind, Power extracted from wind, Betz limit, Lift and drag coefficients, thrust and torque, stream tube model, linear momentum theory, power coefficient, thrust coefficient, axial interference factor. Pitch and stall regulation, power curve, energy calculation.

Wind turbine generators: stand alone systems – schemes and system design, grid-connected systems – types, topology, characteristics, fixed speed and variable speed systems. Power electronic interface.Brakes.Gears.Testing and certification.

Wind farm development and operation: Techno economic feasibility. Government regulations and guidelines, micrositing and layout, use of software in micrositing, selection of equipment, installation and commissioning. Local infrastructure and power evacuation, influence of grid quality and reliability. Operation and maintenance.Central monitoring system and SCADA.

Windfarm performance indices.Economic performance indices. Offshore wind farm development and special considerations. Short term and long term Wind forecasting. Grid code for wind farm operation.

TEXT BOOKS/ REFERENCES:

1.Joshua Earnest and Tore Wizelius, "*Wind Power Plants and Project Development*", PHI Learning Pvt. Ltd., New Delhi, 2011.

2.G L Johnson, "*Wind Energy Systems*", Manhattan, KS, 2004.

3.E. H. Lysen, "*Introduction to Wind Energy, CWD Report 82-1, Consultancy Services Wind EnergyDeveloping Countries*", The Netherlands, May 1983.

4.ErichHau, "*Wind Turbines- Fundamentals: Technologies, Application, and Economics*". Springer -Verlag Berlin -Heidelbeg, 2000.

19RM600 RESEARCH METHODOLOGY 2-0-0-2

Course Objectives:

- To familiarize with modeling, referencing, literature survey, etc
- To design experiments and to analyze results of the experiments
- To prepare technical reports and research papers
- To prepare material for technical presentation and do oral presentation
- To understand the purpose and terms of IPR
- To orient to ethics in research and publication

Course Outcome(CO)

CO.1	Familiarity with literature survey
CO.2	Familiarity with rresearch methodology

CO.3	Planning and executing investigation
CO.4	Analysis of results of a study
CO.5	Oral and written presentation of a study

Unit I:
Meaning of Research, Types of Research, Research Process, Problem definition, Objectives of Research,Research Questions, Research design, Approaches to Research, Quantitative vs. Qualitative Approach,Understanding Theory, Building and Validating Theoretical Models, Exploratory vs. ConfirmatoryResearch, Experimental vs Theoretical Research, Importance of reasoning in research.
Unit II:
Problem Formulation, Understanding Modeling& Simulation, Conducting Literature Review,Referencing, Information Sources, Information Retrieval, Role of libraries in Information Retrieval,Tools for identifying literatures, Indexing and abstracting services, Citation indexes
Unit III:
Experimental Research: Cause effect relationship, Development of Hypothesis, Measurement SystemsAnalysis, Error Propagation, Validity of experiments, Statistical Design of Experiments, FieldExperiments, Data/Variable Types & Classification, Data collection, Numerical and Graphical DataAnalysis: Sampling, Observation, Surveys, Inferential Statistics, and Interpretation of Results
Unit IV:
Preparation of Dissertation and Research Papers, Tables and illustrations, Guidelines for writing the abstract,introduction, methodology, results and discussion, conclusion sections of a manuscript. References,Citation and listing system of documents
Unit V:
Intellectual property rights (IPR) - patents-copyrights-Trademarks-Industrial design geographical indication. Ethics of Research- Scientific Misconduct- Forms of Scientific Misconduct.Plagiarism, Unscientific practices in thesis work, Ethics in science

TEXT BOOKS/ REFERENCES:

1. Bordens, K. S. and Abbott, B. B., “Research Design and Methods – A Process Approach”, 8th Edition, McGraw-Hill, 2011
2. C. R. Kothari, “Research Methodology – Methods and Techniques”, 2nd Edition, New Age International Publishers
3. Davis, M., Davis K., and Dunagan M., “Scientific Papers and Presentations”, 3rd Edition, Elsevier Inc.
4. Michael P. Marder,“ Research Methods for Science”, Cambridge University Press, 2011
5. T. Ramappa, “Intellectual Property Rights Under WTO”, S. Chand, 2008
6. Robert P. Merges, Peter S. Menell, Mark A. Lemley, “Intellectual Property in New Technological Age”. Aspen Law & Business; 6th Edition July 2012

19RE622 RENEWABLE ENERGY LABORATORY II 0-0-4-2

Course Objectives:

- Develop knowledge through software and hardware experimentation on wind energy conversion systems

Course Outcome(CO)

CO.1	Exposure to WTG installation, wind tunnel, wind data collection, etc.
CO.2	Hands on experience on WTG, WTG emulation and testing
CO.3	Familiarity with WAsP, Windographer, Mapper, etc
CO.4	Modeling, simulation and performance analysis of WTG
CO.5	Familiarity with power electronic interfaces used in WECS

Laboratory experiments on wind electric generators, Field measurements and analysis. Software based studies on wind resource assessment and micro-siting, grid-connected WTG systems. Solar thermal systems, energy storage.

19PE718 POWER SYSTEM MODELING3-0-0-3

Course Objectives:

- To learn modeling of various power system components and power electronics devices used in power system.
- To introduce static and dynamic performance analysis of power systems

Course Outcome(CO)

CO.1	Understand the Models of nonelectrical components generally used in power system
CO.2	Develop transformer and synchronous machine models
CO.3	Develop models of Power Electronic devices used in Transmission lines
CO.4	Analyze static and dynamic performance of power systems with FACTS

Modelling of Power System Components: classical methods of modeling. Simplified models of non-electrical components like boiler, steam, hydro-turbine, diesel engine and governor system. Transformer modelling - auto-transformer, tap-changing and phase-shifting transformers. Modelling of Transmission line and Loads.

Modelling of Excitation system: definitions of voltage response ratio and exciter voltage ratings.IEEE excitation systems.Excitation configurations- dc and ac excitations, self and separately excited systems.Basics of Park’s transformation.Modelling of Synchronous machine: Basic flux linkage, voltage and torque equations of synchronous machine - Basics of Park's transformation. The current & flux linkage models using Park's transformation - Models for steady-state and dynamic studies. Simulation and analysis of Synchronous machine connected to an infinite bus. Modelling of Power converters, Modelling of wind and solar power plants. Modelling of FACTS devices, Stability analysis of sample power system models.

TEXT BOOKS/ REFERENCES:

1.K.R.Padiyar, "*Power Systems Dynamics*", B.S. Publications, 2008.

2. Anderson and Fouad, "*Power System Control and Stability– Vol. I*",IEEE Press, New York, 1994.

3. Kundur, "*Power System stability and Control*", McGraw Hill, 1994.

4. Krishna, S," *An Introduction to Modelling of Power System Components*", Springer,2014.

5. Qiuwei Wu, Yuanzhang Sun, "*Modeling and Modern Control of Wind Power*", IEEE press, John Wiley & Sons Ltd, 2018.

6. Sen, Zekai,*"Solar Energy Fundamentals and Modeling Techniques"*, Springer,2008.

19RE701 SOLAR THERMAL ENGINEERING3-0-0-3

Course Objectives:

- Learn the concepts of thermodynamics and heat transfer in buildings, heat exchangers.
- Design solar thermal collectors for various applications and evaluate performance

Course Outcome(CO)

CO.1	Understanding of the concepts of thermodynamics and heat transfer
CO.2	Ability to apply the principles of thermodynamics in energy transfer
CO.3	Ability to analyze and evaluate heat transfer in buildings and heat exchangers
CO.4	Ability to apply principles to collect and measure the solar thermal form of energy
CO.5	Ability to evaluate performance of solar thermal collectors
CO.6	Ability to design solar thermal energy systems for various applications

Fundamentals of Thermodynamics and Heat Transfer: Basics of thermodynamics upto second law – Laws of Thermodynamics – Heat engines, refrigerators and heat pumps; thermodynamic cycles-power and refrigeration cycles; Laws of heat transfer – Thermal resistance network – Heat conduction equation – Critical radius of insulation – Initial and Boundary conditions; Non-dimensional Numbers in heat transfer; Heat transfer from extended surfaces; Heat Exchangers: Types and applications – Overall heat transfer coefficient – LMTD and NTU methods.

Solar radiation measurement instruments – Pyranometer&Pyrheliometer; Solar Thermal Collectors – Liquid Flat plate collector construction and analysis – Thermal resistance network model – Heat transfer correlations – performance characteristics and factors affecting – Concentrating type collectors – Construction and working – Tracking mechanisms – Heliostats with central receiver –Solar Process Loads – Collector Heat Exchanger Factor, Collector Arrays - Series Connections, Series Arrays with Sections Having Different Orientations.

Solar thermal applications – Solar water heaters – Space heating – Active and passive heating – Solar air heaters – Solar chimney; Solar thermal power plants – Low, medium and high temperature systems – Performance analysis; Solar Ponds – Convective and non-convective ponds – Salt gradient solar pond – Experimental studies; Water desalination using solar still; Space cooling and refrigeration.

TEXT BOOKS/ REFERENCES:

1. John A. Duffie and W. A. Beckman, "*Solar Engineering of Thermal Processes*", John Wiley and Sons, 2013.
2. F.P. Incopera and D.P. Dewitt, "*Fundamentals of Heat Transfer*", John Wiley and Sons, 2011.
3. John Twidell and Tony Weir, "*Renewable Energy Resources*", SecondEdition, Taylor and Francis, 2005.
4. Y. A. Cengel& M. A. Boles, "Thermodynamics – *an engineering approach*," Eighth Edition, McGraw Hill education, 2016.
5. Y. A. Cengel& A. J. Ghajar, "Heat and Mass Transfer," Fifth Edition, McGraw Hill education, 2016.

19PE705 ELECTRICAL MACHINE ANALYSIS USING FINITE ELEMENT ANALYSIS 3-0-0-3

Course Objectives:

- To learn basic principles of Finite Element Analysis
- To apply Finite Element Analysis to Electric Machines

Course Outcome(CO)

CO.1	Understand the basic principles of finite element method.
CO.2	Analyze two dimensional problems using finite element method.
CO.3	Determine the electromagnetic parameters of electrical apparatus

CO.4	Design of electrical machines using FEM software tool

Review of Electromagnetic theory, basic principles of finite element method, Aspects regarding heating of electrical machines (ventilation, heating, consequences), Main stages in electromagnetic computation (windings, core, stator, rotor, parameters) performances analysis.

Applications of finite element method to two dimensional fields, linear interpolation, variational method, description of electromagnetic fields, analysis procedure using finite element method, reduction of field problem to a two dimensional problem, boundary conditions, drawing flux line, magnetic energy and co-energy, magnetic forces, determination of electrical parameters.

Cylindrical magnetic devices, analytical study of magnetic devices, finite element analysis, single phase transformer, computation of no load inductance, determination of leakage inductance, algorithm for the construction of magnetizing characteristics of a transformer. Single phase variable reactance, computation of reactance.Design using any FEM tool.

TEXT BOOKS/ REFERENCES:

1.Nicola Bianchi, "*Electrical Machine Analysis Using Finite Elements*", CRC Press, 2005.

2.Cheng D K, "*Fundamentals of Engineering Electromagnetic*", Addison Wesley, 1993.

3.Reece A and Preston T, "*Finite Element Method in Electric Power Engineering*", Oxford University Press, UK, 2000.

19PE709 PROGRAMMABLE LOGIC CONTROLLERS 3-0-0-3

Course Objectives:

- To introduce the working of PLC and its interface.
- To study the basics of ladder logic programming.
- To understand the PLC data organization and instruction set.

Course Outcome(CO)

CO1	Understand the fundamentals of PLC and Ladder diagram
CO2	Illustrate the working of Digital and Analog PLC interface
CO3	Describe the PLC processor Data Organization and programming instructions
CO4	Able to work on a real time problem

Introduction to PLC; Ladder diagram, relay logic, digital and analog PLC interface; input and output modules; PLC processors, processor data organization, basic relay instruction; timer and counter instruction, sequencer instruction, programme flow instruction. Case studies-motor control.

TEXT BOOKS/ REFERENCES:

1. Dunning Gary, "*Introduction to Programmable Controllers*", Third Edition, Thomson Delmar Learning,2006.
2. John R. Hackworth and Frederick D, "*Programmable Logic Controllers: Programming Methods andApplications*", Pearson Education Inc., 2004.
3. Bolton W, "*Programmable Logic Controllers*", Fifth Edition, Elsevier, 2009.
4. John W Webb and Ronald A Reis, "*Programmable Logic Controllers: Principles and Applications*", Fifth Edition, PHI learning Pvt. Ltd., 2009.

Frank D.P., "*Programmable Logic Controllers*", Second Edition, Tata McGraw Hill Publishing Company Limited, 1997.

19PE716 POWER SYSTEM OPERATION AND CONTROL2-0-2-3

Course Objectives:

- To learn operation and control of power system components
- To introduce modeling and design of power system components

Course Outcome(CO)

CO.1	Understand the operating states of power system and various factors related to load variations.
CO.2	Analyze Automatic Generation and Voltage Control loops in power systems.
CO.3	Design components to control voltage and frequency in power system.
CO.4	Evaluate the performance of control loops using modern software tools.
CO.5	Compute economic load dispatch for load frequency control.

Introduction- System load Variation: System load characteristics, Load curve- weekly and annual duration curve, load factor, diversity factor. System State and Transition, Operation of vertical and deregulated power system, Control center functions.Overview of system control: Governor control, LFC, AVR. Linear Models of Synchronous machines- Transient stability- Dynamic Stability- Bi directional power flow in grid connected and islanded modes.

Real power- frequency control:Need for voltage and frequency regulation in power system, basic P-f and Q-V control loops.Fundamentals of speed governing systems and modeling, LFC of Single area and two area systems.Power system stabilizer and its modeling.

Reactive power – Voltage control: Typical excitation system, static and dynamic analysis, effect of generator loading, static shunt capacitor/reactor VAR compensator, synchronous condenser, tap changing transformer, Static VAR system, modeling, system level voltage control.

TEXT BOOKS/ REFERENCES:

1. Olle. I. Elgerd, "*Electric Energy Systems Theory- An Introduction*", Tata McGraw Hill Publishing Company Ltd., New Delhi, 2004.
2. D. P. Kothari and I. J. Nagrath, "*Modern Power System Analysis*", Tata McGraw Hill Publishing Company Ltd., New Delhi, 2005.
3. Allen .J. Wood, Bruce.F.Wollenberg and Gerald B. Sheble, "*Power Generation Operation and Control*", Third Edition, John Wiley and Sons, 2013.
4. L.K.Kirchmayer, "Economic Operation of Power System", John Wiley and Sons, 1953.
5. Kundur, "*Power System stability and Control*", McGraw Hill, 1994.

19RE702 POWER ELECTRONICS FOR ENERGY SYSTEMS 3-0-0-3

Course Objectives:

- Learn characteristics of power electronic components and operation of various converters and voltage regulators
- Design converters for voltage regulation and VVVF applications
- Learn grid synchronization and protection of power converters

Course Outcome(CO)

CO.1	Understanding of characteristics of power semiconductor switches, various converters and voltage regulators
CO.2	Ability to analyze the operation of various converters, and voltage regulators under continuous conduction mode with R,RL & RLE loads
CO.3	Ability to design various converters for voltage regulation and variable voltage-variable frequency applications
CO.4	Ability to control the converters in grid synchronization applications for power flow control.

CO.5	Ability to design protection circuits and magnetic elements in various power converters.

Power semiconductor switches: Power diodes, Thyristors, MOSFETS, and IGBT. IPMs. Switch waveforms and power loss calculations. Non sinusoidal waveform analysis - Harmonic standards

AC voltage controllers: Thyristor controlled reactor (Reactive power compensation in wind electric generator systems) - Soft starters for Wind electric systems.

Converters: AC-DC converters and DC– DC converters (For Solar PV & Wind energy applications). Power factor correction topologies and control with dc-dc converters for PMSGs.

Inverters: Single phase and three phase sine PWM inverters – design of dc link voltage - Harmonic analysis - rectifier mode of operation- AC-DC-AC back-back converters in renewable energy applications (Off and on grid) - Grid synchronization and PLL - Islanding operation. Control of converters for fault operation - Filter design.Relevant IEEE and IEC standards for renewable energy systems.

TEXT BOOKS/ REFERENCES:

1. Mohan, T.M.Undeland, and W.P.Robbins, "*Power Electronics, Converters, Applications and Design*", Third Edition, John Wiley and Sons Inc., 2006.
2. Teodorescu, Remus, Marco Liserre, and Pedro Rodriguez. *Grid converters for photovoltaic and wind power systems*. Vol. 29. John Wiley & Sons, 2011.
3. Abu-Rub, Haitham, Mariusz Malinowski, and Kamal Al-Haddad. *Power electronics for renewable energy systems, transportation and industrial applications*. John Wiley & Sons, 2014.
4. Simões, Marcelo G., and SudiptaChakraborty. *Power Electronics for Renewable and Distributed Energy Systems: A Sourcebook of Topologies, Control and Integration*. Springer-Verlag London, 2013.

19RE703FLEXIBLE AC AND HIGH VOLTAGE DC TRANSMISSION SYSTEMS 3-0-0-3

Course Objectives:

- Learn operating principles and control of FACTS and HVDC systems
- Analyze the performance of corrective equipment in power system

Course Outcome(CO)

CO.1	Understanding of the basic concepts, principles and operation of power compensators

CO.2	Ability to decide effective control strategy for the compensators
CO.3	Ability to aanalyze the performance of corrective equipment under different operating scenarios
CO.4	Familiarity with HVDC System and components

Introduction to transmission system interconnections - Power flow in AC system - loading capability and dynamic stability - IEEE Definitions. Shunt Compensation: Objectives – Configuration - Control Scheme and operating characteristics of Variable impedancecompensators - Thyristor switched capacitor(TSC)- Thyristor switched reactor(TSR) - Thyristor controlled reactor(TCR) - Fixed Capacitor-Thyristor Switched Reactor(FC-TSR) - Fixed capacitor-Thyristor controlled reactor(FC-TCR) - Thyristor switched capacitor– Thyristor controlled reactor(TSC-TCR) - switched converter type compensators(STATCOM) and hybrid shunt compensators.

Series Compensation:objectives – configuration - Control scheme and operating characteristics of variable impedance series compensators - GTO Controlled Series Capacitor (GCSC) Thyristor Switched Series Capacitor (TSSC)-Thyristor Controlled Series Capacitor(TCSC) and switching converter type series compensator(SSSC). Objectives, modes of operation of Voltage Regulatorand Phase angle Regulators. Multifunctional FACTS Controllers: Unified Power Flow Controller (UPFC) Interline Power Flow Controller (IPFC) – configuration and control scheme for real power and reactive power control applications. Advances in FACTS Technology – Applications – Case studies.

Components of HVDC Transmission system: Converter, Transformer - Smoothing reactor - Harmonic Filter - Types of HVDC Links - Basic powerconversion principle - rectifier and inverter operation - Principle of DC Link control -converter control characteristics - Firing angle control - Current and Extinction angle control - Starting and Stopping of DC link - power control - Effect of smoothing inductance on the system Reactive power control - Comparison of AC and DC Transmission – Applicationand Modern Trends in HVDC system.

TEXT BOOKS/ REFERENCES:

1. Hingorani N. G "*Understanding FACTS - Concepts and Technology of Flexible AC Transmission Systems*", IEEE Press, 2000.

2. YongHua Song and Allan T Johns, "*Flexible AC Transmission System*", The Institution of Electrical Engineers, UK, 1999.

3. K. R. Padiyar "*FACTS Controllers in Power Transmission & Distribution*", Ashan Publishers, 2009.

4. K.R. Padiyar, "*HVDC Power Transmission Systems*", Second Edition, New Academic Science Publishers,

2011
5. Vijay. K. Sood, "*HVDC and FACTS Controllers – Application of Static Converters in Power Systems*", Kluwer Academic Publishers, Massachusetts, 2004.

19RE704 AERODYNAMICS AND WIND TURBINES 3-0-0-3

Course Objectives:

- Learn aerodynamics principles and design aspects adopted in design of wind turbine blades.
- estimate the aerodynamic performance of wind turbines.

Course Outcome(CO)

CO.1	Understanding of basic terminologies and concepts in aerodynamics
CO.2	Ability to understand and apply potential flow theory to various two dimensional problems
CO.3	Knowledge of Prandtl's lifting line theory and ability to apply it for finite wings and rotor blades
CO.4	Ability to estimate the aerodynamic performance of wind turbines; know methodologies to design wind turbine rotors.

Basic equations: Continuity, momentum and energy equations. Application of momentum equation.Calculation of drag on two -dimensional body.Inviscid, incompressible flow: Theoretical solutions of potential flow past different bodies. d' Alembert's paradox.

Incompressible flow over aerofoils, aerofoil nomenclature, characteristics, vortex sheet, kutta condition.Kelvin's Circulation Theorem.Classical thin aerofoil theory, Symmetric and cambered aerofoils, Basic design concepts.Prandt's Lifting line Theory. Numerical source panel and vortex panel methods. Stream tube model, linear momentum theory.

Wind Turbines: Types, Rotor elements; Horizontal and vertical axis wind turbines, slip stream theory. Calculation of axial thrust and efficiency, Pitch and stall regulation. Lift and drag coefficients; thrust and torque calculations, Tip losses, Characteristics of horizontal axis wind turbines and power curve. Concepts of blade design. Wind pumps. Matching of pump and turbine characteristics.

TEXT BOOKS/ REFERENCES:

1. DNV- Riso, “*Guidelines for Design of Wind Turbines*”, Second Edition, Riso National Laboratory, Denmark,2002.
2. Martin O. L. Hansen, “*Aerodynamics of Wind Turbine*”, James & James (Science Publishers) Ltd., London,2000.
3. Lysen, E. H., “*Introduction to Wind Energy*”, CWD Report 82-1, Consultancy Services Wind Energy Developing Countries, The Netherlands, May 1983.
4. Erich Hau, “*WindTurbines Fundamentals, Technologies, Application and Economics*“, Springer-Verlag Berlin -Heidelbeg, 2000.

19RE705 WIND ELECTRIC GENERATORS 3-0-0-3

Course Objectives:

- Learn principles, characteristics, modelling and performance analysis of different topologies of wind turbine generators
- Familiarize with enabling FRT capability, grid code compliance, MPPT, WT-generator matching, etc.

Course Outcome(CO)

CO.1	Understanding of principles and characteristics of wind turbines and electric generators
CO.2	Modeling and analysis of different types of generators used in WTG
CO.3	Understanding of power quality issues in WTG and remedies
CO.4	Understanding of FRT issues in WTG, enabling FRT capability and grid code compliance
CO.5	Concepts of performance improvement of WTG like MPPT, WT-generator matching, etc.

Status of Wind Power Technologies - Wind Turbine Generator Topologies- Wind turbine characteristics and controls.

Induction generator - Squirrel cage and slip ring machines, equivalent circuit, Torque-slip characteristics, Real and reactive power, self-excited and grid connected systems, Generalized model of electrical machines- Clarke’s and Park’s transformation, modeling in synchronous reference frame. Doubly fed inductiongenerators- Brush type and Brushless types, four quadrant operation, modeling and Control of Doubly-fed Induction Generators for Wind Turbines, Rotor side converter, Grid side converter.

Synchronous generators-Wound type and permanent magnet types, power angle characteristics, Real and reactive power, Salient and Non salient poles;Modeling and control of Full-scale Converter Wind Turbine Generator-Clustering based Wind Turbine Generator Model Linearization-Adaptive Control of Wind Turbines for Maximum Power Point Tracking-Distributed Model Predictive Active Power Control of Wind Farms with and without energy storage-Model Predictive Voltage Control of Wind Power Plants-Control of Wind Farm Clusters- Challenges with Wind Power Integration -Grid Code Requirements for Wind Power Integration-Power quality issues with grid connected wind electric generators; Reactive power compensation; Harmonics; Voltage unbalance; Voltage flicker; Voltage sag; Fault Ride Through Capability-Low Voltage Ride Through Capability, Grid Code; Voltage Operating Range , Frequency Operating Range and Frequency Response, Methods to improve performance of WTG- Fault Ride Through Enhancement of VSC-HVDC Connected Offshore Wind Power Plants-Power Oscillation Damping from VSC-HVDC-connected Offshore Wind Power Plants.

TEXT BOOKS/ REFERENCES:

1. Qiuwei Wu, Yuanzhang Sun, “Modeling and Modern Control of Wind Power”, IEEE press, John Wiley & Sons Ltd,2018
2. J.F.Manwell, J.G.McGowan and A.L.Rogers, “*Wind Energy Explained-Theory, Design and Application*”, John Wiley and Sons Ltd., 2009.
3. Olimpo Anaya Lara, Nick Jenkins, JanakaEkanayaka, Phill Cartwright and Mike Hughes, “*Wind EnergyGeneration-Modeling and Control*”, John Wiley and Sons Ltd., 2009.
4. M.GodoySimoes and Felix A.Farret, “*Renewable Energy Systems-Design and Analysis With InductionGenerators*”, CRC Press, 2004.
5. Fernando D.Bianchi, Hernan De Battista and Ricardo J.Mantz, “*Wind Turbine Control Systems-Principles,Modelling and Gain Scheduling*”, Springer-Verlag London Ltd., 2007.
6. Joshua Earnest and Tore Wizelius, “*Wind Power Plants and Project Development*”, PHI, 2011.

19RE706 APPLIED COMPUTATIONAL FLUID DYNAMICS 3-0-0-3

Course Objectives:

- Learn concepts of fluid mechanics and heat transfer
- Apply CFD techniques in thermal systems.
- Apply CFD techniques in the modelling of wind power.

Course Outcome(CO)

CO.1	Ability to apply concepts of fluid mechanics and heat transfer
CO.2	Ability to analyze the discretization methods
CO.3	Ability to analyze different schemes in finite element methods
CO.4	Ability to evaluate thermal systems using CFD techniques
CO.5	Ability to apply CFD techniques in wind power modeling

Introduction: Models of fluid flow, Governing equations, continuity equation, momentum equation, Initial and boundary conditions. Discretization: Introduction to finite differences,Differences equation, Forward, backward and central difference schemes; explicit and implicit methods. Errors and Analysis of stability, Upwind schemes. Finite volume analysis. CFD Techniques: Lax-Wendroff technique, Mac Cormack's technique. Alternating direction implicit technique. Pressure correction technique: Philosophy of pressure correction method, pressure correction formulae, SIMPLE algorithm. Application: Design optimization of turbine blade profile, CFD Modeling of wind farms (any one technique).

TEXT BOOKS/ REFERENCES:

1.John D. Anderson, "*Computational Fluid Dynamics*",McGraw Hill Higher Education, 1995.

2.Joel H. Ferziger and MilovanPeric, "*Computational Methods for Fluid Dynamics*",Springer, 2001.

3.K. Muralidhar and T. Sundararajan, "*Computational Fluid Flow and Heat Transfer*", Narosa Publication, 1995.

19RE707 ENERGY STORAGE SYSTEMS 3-0-0-3

Course Objectives:

- Familiarize with various energy storage systems
- Design and model different types of energy storage systems for RE applications
- Evaluate performance of various storage systems in various applications.

Course Outcome(CO)

CO.1	Familiarity with various energy storages systems.
CO.2	Ability to evaluate performance of various storage systems
CO.3	Ability to model different types of energy storage systems

CO.4	Ability to design Energy Storage Systems for various applications

Introduction, Thermal Energy Storage, Energy Storage in Organic Fuels, Mechanical Energy Storage, Pumped Hydro Storage, Electromagnetic Energy Storage, Capacitor and Magnetic Systems, Super Conducting Magnetic Energy Storage, Electrochemical Energy Storage,Smart Energy Management - HighCurrent Density Battery charging techniques with Battery management system, Hybrid charging techniques in Electric vehicles, Hydrogen and synthetic fuels, Fuel Cells, Consideration on the choice of Energy Storage Systems, Integration of Energy Storage Systems, Optimizing Regimes for Energy Storage in Power Systems, Distributed energy storage with grid interface.

TEXT BOOKS/ REFERENCES:

1. Robert A. Huggins, "*Energy Storage*", Springer New York Heidelberg Dordrecht London, 2010.
2. A. Ter-Gazarian, "*Energy Storage for Power Systems*", IET Energy Series 6, London, 2008.
3. Richard Baxter, "*Energy Storage – A Non-Technical Guide*", Penn Well, Oklahoma, 2006.
4. Ralph Zit, "*Energy Storage- A New Approach*", Wiley – Scrivener, Wiley Publishers, 2010.
5. Ahmed FaheemZobaa, "*Energy Storage – Technologies and Applications*", In Tech Publisher, 2013.

19RE708 SMART GRID 2-1-0-3

Course Objectives:

- To be aware of the significance and requirements of smart grid
- To familiarize with communication technologies and real time monitoring schemes
- To learn phasor and frequency estimation
- To familiarize with standards and regulations for SG
- To design smart solutions for power systems

Course Outcome(CO)

CO.1	Understanding the background of evolution of smart grid
CO.2	Familiarity with communication technologies and real time monitoring schemes of smart grid
CO.3	Familiarity with energy storage and its management on SG
CO.4	Familiarity with performance analysis tools for SG

CO.5	Familiarity with standards and regulations for SG

Smartgrid definition,Smartgrid vs conventional grid,SmartGrid technologies -Power system and ICT in Generation,Transmission and Distribution.Basic understanding of power systems. Evolution of power electronics in power system applications, Smart Grid features (Distributed generation, energy storage, Demand Dispatch,Demand Response, Advanced Metering Infrastructure,Wide Area Monitoring System, Wide Area Control System.Sensors - CT, PT, Devices – Intelligent Electronic Device, Phasor Measurement Unit,Phasor Data Concentrator, relays, Demand Response Switch.Communication- Standards, Technology and protocols. Energy management on smart grid – Energy Management System, Dynamic energy storage management, Real time monitoring systems, concepts of cloud and IoT. IoT applications in power system – IoT on microgrids; IoT for RE generation control, load management, dynamic pricing etc; IoT for domestic prosumers.

TEXT BOOKS / REFERENCES:

1. James Momoh, "*Smart Grid: Fundamentals of Design and Analysis*", Wiley-IEEE Press, March 2012.
2. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu and Akihiko Yokoyama, "*SmartGrid:Technology and Applications*", Wiley, February 2012.
3. NouredineHadjsaïd and Jean-Claude Sabonnadière, "*Smart Grids*", Wiley-ISTE, May 2012.
4. Ali Keyhani and Muhammad Marwali, "*Smart Power Grids 2011*", Springer, 2011.
5. Mini S. Thomas, John Douglas McDonald,"*Power System SCADA and Smart Grids*",CRC Press, April 2015.
6. Vijay Madisetti and ArshdeepBahga, "*Internet of Things: A Hands-on Approach*", Hardcover – Import, 2014.

19RE709 ELECTROCHEMICAL ENERGY SYSTEMS 3-0-0-3

Course Objectives:

- **Learn the functionality, operation and standards involved in various electrochemical devices used in support of renewable energy.**

Course Outcome(CO)

CO.1	Understanding of the background of electrode potential and emf generation
CO.2	Familiarity with the primary and secondary batteries

CO.3	Understanding the operation, different types and working principle of fuel cell
CO.4	Familiarity with the various international standards and performance characteristics of electrochemical devices

Background Theory: Origin of potential –electrical double layer – reversible electrode potential-emf series-reference and indicator electrodes - Nernst equation – Butler-Volmerequation - Activation, concentration and IR overpotentials - Tafel plots - Primary and secondary batteries: The chemistry,
fabrication and performance aspects, packing classification and rating of zinc and lithium primary batteries-Lead acid, nickel, silver and lithium ion secondary batteries-VRLA batteries-Sodium-beta and Redox batteries for vehicles - Thermally activated reserve batteries.
Fuel Cells: Working principle, fabrication of electrodes and other components, and environmental aspects of Proton Exchange Membrane Fuel Cells, Alkaline fuel cells, Phosphoric acid, Solid oxide, Molten carbonate, Direct methanol fuel cells - Reformation clean up and storage for hydrogen –Testing and Assessment of Batteries - Shelf life and service life– effect of temperature and pressure – effect of aging –memory effect – test conditions, mechanical and environmental, load and electromagnetic compatibility testing. Selected international standards – performance characteristics –Peuckert discharge curves, Ragone plots, Supercapacitors.

TEXT BOOKS/ REFERENCES:

1.Dell, Ronald M Rand and David AJ, "*Understanding Batteries*", Royal Society of Chemistry, 2001.
2.M. AuliceScibioh and B. Viswanathan, "*Fuel Cells – Principles and Applications*", University Press, India, 2006.
3.F. Barbir, "*PEM Fuel Cells: Theory and Practice*", Elsevier, Burlington, MA, 2005.
4.David Linden and Thomas B Reddy, "*Handbook of Batteries*", Third Edition, McGraw-Hill, 2001.
5.DerekPletcher and Frank C. Walsh, "*Industrial Electrochemistry*", Blackie Academic and Professional, 1993.

19RE710 PROJECT MANAGEMENT 3-0-0-3

Course Objectives:

- Familiarize with determinants of operations system
- Handle project execution tools and techniques, recognize various project network problems and solve, and, study operational issues of project organizations

Course Outcome(CO)

CO.1	Understanding of differences between past and present methods of managing projects.
CO.2	Ability to identify and recommend the determinants of effective and efficient use of an operations system.
CO.3	Skill in using the project execution tools and techniques.
CO.4	Ability to recognize various kinds of project network problems and identify appropriate quantitative analytical tools to solve those problems.
CO.5	Ability to analyze and evaluate operational issues of project organizations.

Project Life Cycle Concept; Nature of Project Management: An overview of Project Management. Scope Management. PM tools & techniques: using MS Project: a) Time b) Resources, c) Cost, d) Updating. Project Feasibility.Project Appraisal and Simulation.Project Accounts. Project Design: Detailed Project Report.
Project Execution: Procurement, Project Control, Earned Value Construction Resource Plan, Engineering Management, Site Management, Project Reviews Role of Agencies. Behavioural aspects of PM: PM Organization, Project Teams, Project leadership. Project Quality Management. Project Management Information System. Project Risk Management.Project Termination. Project Evaluation.PM Case Study.

TEXT BOOKS/ REFERENCES:

1. Meredith, Jack R, Samuel J and Mantel Jr., "*Project Management- A Managerial Approach*", John Wiley, 1995.
2. Klastorin Ted, "*Project Management, Tools, and Trade-offs*", John Wiley, 2004.
3. Mantel, Meredith, Shafer and Sutton A, "*Core Concepts of Project Management*", John Wiley, 2001.

19RE711 ENERGY FORECASTING AND MODELING 3-0-0-3

Course Objectives:

- Develop energy system models for short term and long term forecasting
- Develop energy optimization models for different scenarios and use in energy

Outcome(CO)

CO.1	Understanding of the scenario of energy management and forecasting relevant to climatic change mitigation.
CO.2	Ability to develop different energy system models for short term and long term forecasting.
CO.3	Ability to quantify the sensitivity of different energy system models according to forecast accuracy
CO.4	Knowledge on various optimization techniques and development of energy optimization models for different scenarios
CO.5	Ability to simulate various energy forecasting models with different optimization methods.

Energy Scenario: Role of energy in economic development and social transformation: Energy & GDP, GNP and its dynamics-Energy Sources and Overall Energy demand and Availability-Energy Consumption in various sectors and its changing pattern-Status of Nuclear and Renewable Energy: Present Status and future promise.

Forecasting Model: Forecasting Techniques-Regression Analysis-Double Moving Average-Double Experimental Smoothing-Triple Exponential Smoothing– ARIMA model-Validation techniques–Qualitative forecasting–Delphi technique-Concept of Neural Net Works.

Optimization Model: Principles of Optimization-Formulation of Objective Function -Constraints-Multi Objective Optimization–Mathematical Optimization Software–Development of Energy Optimization Model -Development of Scenarios– Sensitivity Analysis.

TEXT BOOKS / REFERENCES:

1.S. Makridaki s, "*Forecasting Methods and Applications*", Wiley 1983.

2. Yang X.S., "*Introduction to Mathematical Optimization: From Linear Programming to Metaheuristics*", Cambridge, Int. Science Publishing, 2008.

3. Armstrong, J.Scott (ed.),"*Principles of Forecasting: A Hand Book for Researchers and Practitioners*", Norwell, Masschusetts: Kluwer Academic Publishers.2001

19RE712 OCEAN ENERGY CONVERSION 3-0-0-3

Course Objectives:

- Recapitulate concepts of thermodynamics and apply in refrigeration cycles.
- Learn ocean thermal, tidal and wave energy conversion technologies and the performance evaluation
- Study ocean bio-energy resources and ocean geothermal energy

Course Outcome(CO)

CO.1	Ability to apply concepts of thermodynamics in power and refrigeration cycles
CO.2	Understanding of ocean energy resources
CO.3	Ability to analyze and evaluate ocean thermal energy conversion methods
CO.4	Ability to analyze the tidal energy conversion systems
CO.5	Ability to analyze and compare various ocean wave energy converters
CO.6	Ability to evaluate the ocean bio-energy resources and ocean geothermal energy

Fundamentals of thermodynamic cycles – power and refrigeration cycles – Rankine cycle – components of a power plant – cogeneration; Ocean Energy – Environmental impacts of ocean energy utilization – Ocean energy routes; Ocean Thermal Energy Conversion – Open and closed cycles for operation – Efficiencies of OTEC plants and their influence on plant size – Cogeneration of electricity and fresh water from open cycle OTEC; Tidal Energy –Origin of tides – Single basin and Double basin systems – Tidal plants in India and around the world in operation;

Wave energy – Parameters of progressive wave – Equation of wave – Energy and power in ocean waves - Types of wave energy convertors – Dolphin-Buoy type, Oscillating float-air pump type, three-raft type converters; Ocean biomass energy – Principal marine bio-energy resources – Kelp bio-energy conversion process; Ocean Geothermal Energy – Availability and limitations – Conversion methods.

TEXTBOOKS/ REFERENCES:

1. M. M. El-Wakil, "*Power Plant Technology*", McGraw Hill, 2010
2. A. W. Culp Jr, "*Principles of Energy Conversion*", McGraw Hill, 2001
3. RH Charlier, Charles W Finkl, " *Ocean ENERGY: Tide and Tidal Power*", Springer, 2009.
4. W H Avery, Wu, "*Renewable Energy from the Ocean – A guide to OTEC*", Oxford University Press, 1994.
5. Joao Cruz, "*Ocean Wave Energy – Current Status and Future Prospectives*", Springer, 2008.

19RE713COMPUTATIONAL OPTIMIZATION THEORY – LINEAR AND NON-LINEAR METHODS **3-0-0-3**

Course Objectives:

- Learn linear and non-linear optimization methods
- Solve engineering problems by applying linear and non-linear optimization

Course Outcome(CO)

CO.1	Understanding different types of Optimization Techniques in engineering problems.
CO.2	Knowledge of gradient based Optimizations Techniques in single variables as well as multivariables(non-linear).
CO.3	Ability to apply linear programming, transportation problems and interior point methods on real world problems
CO.4	Ability to solve engineering problems by applying Linear and Non- Linear optimization techniques

Single Variable optimization - Optimality criteria,Bracketing methods- Exhaustive search method, Bounding phase method, Region elimination methods - Interval halving, Fibonacci search, Golden section search, Point estimation, Successive quadratic search, Gradient, Newton Raphson, Bisection, Secant and Cubic search method.

Multivariable Optimization - Optimality criteria, Gradient based methods - Steepest descent, Conjugate direction, Conjugate gradient, Newton's, Levenberg Marquardt, Quasi Newton, Variable metric and BFGS method. Constrained Optimization - Karush-Kuhn-Tucker optimality criteria, Direct methods - Frank-Wolfe method, Cutting plane method, Method of feasible direction - Gradient projection method, Indirect methods- Transformation techniques,Penalty function methods for mixed equality and inequality constraints. Geometry of Linear programming problems, Simplex methods, Duality in Linear programming, Markov Chain Monte Carlo Methods, Dynamic Programming in the context of graph theory applications.

Transportation problems. Interior Point methods - Primal-Dual Path-FollowingAlgorithm, Primal-Dual Model, Duality Theory and the Central Path, Primal-Dual Newton Method, Strategies in Path-following Algorithms, Self-Regular Functions and their Properties, Primal-Dual Algorithms Based on Self-Regular Proximities.

TEXT BOOKS/ REFERENCES:

1.S. S. Rao, "*Optimization Theory and Practice*", Fourth Edition, John Wiley and Sons, 2009.

2. Kalyanmoy Deb, "*Optimization for Engineering Design Algorithms and Examples*", Prentice Hall of India, New Delhi, 2004.

3. Edwin K.P. Chong and Stanislaw H. Zak, "An Introduction to *Optimization*", Second Edition,Wiley-Interscience Series in Discrete Mathematics and Optimization, 2004.

4. M. AsgharBhatti, "*Practical Optimization Methods: with Mathematical Applications*", Springer Verlag Publishers, 2000.

19RE714 **ELECTRIC POWER QUALITY** **3-0-0-3**

Course Objectives:

- Analyze power quality issues and learn mitigation techniques.
- Design power quality improvement schemes and analyze the performance

Course Outcome(CO)

CO.1	Ability to identify sources and effects of various power quality issues.
CO.2	Ability to aanalyze the behaviour of power quality events and categorize them based on the recommended standards
CO.3	Ability to design and develop suitable mitigation techniques
CO.4	Ability to aanalyze the performance of power quality improvement schemes

Introduction to Electric Power Quality- Voltage Variations - Imbalances- Voltage Fluctuations- Distortion- Power Frequency variation.Power Quality measures and Indices: Sources of Voltage Sag- Calculation ofVoltage Sag/ Swell under faults- capacitor switching- motor starting- imbalance.Symmetrical Components- Simple protection methods.

Harmonic studies- Electric Circuit Analysis and power assessment under non-sinusoidal conditions- Fourier Analysis- FFT Analysis- Harmonic propagation in large Network.Effect of Harmonics on custom side and Utility side. Compensation Techniques- Shunt and Series Compensators - Static VAR Compensators- Harmonic filters. Case studies

TEXT BOOKS/ REFERENCES:

1. AlexanderKusko and Marc Thompson, "*Power Quality in Electrical Systems*", McGraw-Hill, 2007.
2. Ewald and Mohammad Masoum, "*Power Quality in Power Systems and Electrical Machines*", Elsevier Academic Press, 2008.
3. George G. Wakileh, "*Power System Harmonics-Fundamentals, Analysis and Filter Design*", Springer-Verlag, 2001.
4. Math J. Bollen, "*Understanding Power Quality Problems-Voltage Sags and Interruptions*", John Wiley and Sons, New Jersey, 2000.

5. EnriqueAcha and Manuel Madrigal, “*Power Systems Harmonics-Computer Modeling and Analysis*”, John Wiley and Sons Ltd., 2001.

19RE715 DISTRIBUTED GENERATION 3-0-0-3

Course Objectives:

- Review common DG technologies
- Design power electronic interfaces and energy storage for micro grid applications.
- Familiarize with policies and regulations

Course Outcome(CO)

CO.1	Understanding of the background of promotion of DG and comparison of DG with centralized generation
CO.2	Technical and general knowledge on wind, PV and hybrid systems
CO.3	Familiarity and system design capability in power electronic interfaces
CO.4	System design capability in micro grid with energy storage
CO.5	Understanding of policies and regulations

Overview of Wind and Solar photovoltaic power generation system - Distributed Generation –Reasons for DG – Technical Impacts of DG – Economic impacts of DG – Barriers to DG development – Recommendation and guidelines to DG planningPower Electronic Interface for Photovoltaic energy conversion systems – Grid Connected Mode, Standalone mode – Design of converters, Sizing of battery storage system - Current controller for Grid connected PV system, Bidirectional converter, Power Conditioner – Control of converter for battery storage system. Power Electronic interface for wind energy conversion systems-SCIG, DFIG concept – Power converter topologies - Design of dual bi-directional converter with DC-link capacitance, Design of ac filter – inductor design, capacitor design – rotor side and grid side converter control, dc-link control - Grid Synchronization and Phase locking – intentional and unintentional islanding – Control of grid connected converters. Design of Hybrid wind-solar, and wind-hydro standalone systems with dual bi-directional converters: Case studies, Design and simulations

TEXT BOOKS/ REFERENCES:

1. Loi Lei Lai and Tze Fun Chan, "*Distributed Generation-Induction and Permanent MagnetGenerators*", IEEE Press, 2007.
2. Haitham Abu-Rub, Mariusz Malinowski and Kamal Al-Haddad, "*Power Electronics for RenewableEnergy Systems, Transportation and Industrial Applications*",Wiley Publishers, June 2014.
3. Massey, G. W., "*Essentials of Distributed Generation Systems*", Jones & Bartlett Learning, 2010.
4. Bollen, M. H., and Hassan, F., "*Integration of Distributed Generation in the Power System*", Vol. 80, John Wiley and Sons, 2011.

19RE798/ 19RE799 DISSERTATION 8/12

Course Objectives:

1. To review the literature and formulate a research problem
2. To develop skill in use of computational and analytical tools
3. To carry out the investigation and analyze the observations
4. To communicate the findings orally as well as in writing
5. To familiarize with project management

Course Outcomes (CO)

18PE798 Dissertation	CO.1	Understand research methodology
	CO.2	Plan and execute Projects
	CO.3	Survey and review literature
	CO.4	Choose computational and analytical tools and design experiments
	CO.5	Communicate technical content orally as well as in writing with added skill
18PE799 Dissertation	CO.1	Plan and manage projects with skill
	CO.2	Analyse results and acquire domain knowledge
	CO.3	Use computational and analytical tools with skill
	CO.4	Demonstrate skill in technical communication
	CO.5	Comprehend and disseminate knowledge

Each student should select and work on a topic related to his/her field of specialization duringsummer of second semester under the supervision of a faculty member. During third and fourth semester each student should work on the selected topic under the supervision of a faculty member. By the end of each (third and fourth) semester the student has to prepare a report in the approved format and present it.